INTERNATIONAL SOURCE BOOK ON ENVIRONMENTALLY SOUND TECHNOLOGIES FOR WASTEWATER AND STORMWATER MANAGEMENT

compiled by
UNEP International Environmental Technology Centre (IETC)

in collaboration with
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Preface

This 'International Source Book on Environmentally Sound Technologies for Wastewater and Stormwater Management' is a sequel to IETC's successful publication 'International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management'. The urgent need for information on how to deal with wastewater is clearly shown by the fact that nearly 3 billion people are without adequate sanitation and its impact on health, medical bills, consequent loss of economic productivity and environmental degradation.

UNEP-DTIE-IETC has a mandate to assist in the transfer of environmentally sound technologies to address urban environmental problems. Our response to the urgent problem noted above and expressed in the numerous enquiries on the subject is in part the compilation of a source book and the dissemination of the information as widely as possible. Training materials based on the source book are being simultaneously produced. Besides the printed version the Source Book and Training Materials are also made available in CD-ROM version, and also through IETC's web based data base maESTro. A pilot training workshop for the Source Book and Training Materials was conducted in Rio de Janeiro on 27 – 31 March 2000 with participants from countries in Central and South America.

Begun with an International Experts Meeting in Osaka, 6 – 8 May 1998, jointly organised by IETC in collaboration with WHO UEH, GEC, ILEC, I am pleased that the ideas, concepts and critiques expressed at that meeting have come to fruition in this publication. While we do not claim to have the 'complete' solution for the complex water and sanitation problems faced by many nations, especially in the developing world, this book is offered as a guide that will lead planners and managers to many other possibilities and contacts.

This Source Book complements UNEP's Practical Policy Guidance for the implementation of the Global Programme of Action (GPA) for the protection of the marine environment from land based activities. Much of the pollution from land based activities come with wastewater and stormwater. Though approached from different angles the two publications are consistent in their message.

Dr Steve Halls

Director
United Nations Environment Programme
Division of Technology Industry and Economics
International Environmental Technology Centre

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Dr. Bernd H. Dieterich, Environmental Consultant, France (West Europe)
Dr. Ute Enderlein, Consultant to WHO, Geneva (East Europe)
Professor Lekan Oyebande, University of Lagos, Nigeria (Africa)
Professor Muhammad Shatanawi, University of Jordan (West Asia)
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Special thanks are extended to all the above.

Introduction

The deterioration of water quality and the consequence public health problems facing many communities worldwide have been recognised for sometime. The United Nations Water Decade (1981-1990) was a major initiative to address the need to provide safe drinking water and sanitation to the two-thirds world without access to these. These problems still exist due to the increasing world population, and the proportion of communities without adequate sanitation has remained at approximately two thirds. These problems are compounded by the rapid migration of rural population to the fringes of cities. This trend of urbanisation has been forecast to continue for sometime into the future. Communities growing rapidly around urban areas are also those with little resources and with low incomes.

Urban managers are faced with the problem of how to provide adequate wastewater and stormwater services, and how to allocate priorities with competing demands for other urban infrastructure such as roads, hospitals and schools. Communities themselves are aware on a daily basis of the lack of services and are similarly confronted by the problem of how to overcome them with very limited available resources within the community. Although these problems are severe in urban areas, many rural communities are also faced with poor or deteriorating sanitation facilities.

Developing countries experience the largest share of the problems described above. Countries in economic-transition also suffer from inadequate or deteriorating infrastructure needing restoration. Even in the developed countries questions have been asked as to whether the current way of providing wastewater and stormwater infrastructure is environmentally sustainable in the longer term.

Purpose and intended audience of the Source Book

The solution to the problem of lack of wastewater and stormwater management does not lie simply in expending more of the limited available funds. Access to information has been identified as a major issue, and is the reason for this Source Book. It follows an earlier publication by UNEP-IETC covering the management of municipal solid waste (International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management), and for largely the same reason. Lessons learned from the adoption or adaptation of technologies in a particular situation have not often reached people elsewhere who can benefit from them. Practices that are deemed to constitute 'environmentally sound technologies' in one place are not generally known in another. A case in point is the highly successful low-cost 'condominium sewerage' first practised in Brazil but largely unknown elsewhere. There also appears to be a lack of appreciation amongst those with the responsibility for providing wastewater treatment of the basis of the treatment technology. High technology processes, such as the activated sludge process, have been equated with better-treated wastewater, when simpler technologies, such as lagooning, can achieve the same or better quality water. The scientific basis for the physical and biochemical processes is largely the same for both, and the same processes operate in natural purification of human excreta. Thus providing information and understanding, and where further information can obtained, is an aim of the Source Book. In addition the Source Book attempts to provide guidance on how to synthesise the available information for application in a particular setting.

The primary intended audience of the Source Book is decision-makers who are involved in providing wastewater and stormwater services. Decision-making takes place at various levels. Politicians/ top ranking government officials/ city mayors and city managers represent one level, where prioritising the need for the services and providing funding is the concern. Professionals provide advice to the above and are involved in implementing wastewater and stormwater projects. Community leaders need to be involved in any service provision to the community. The private sector may be involved in financing, constructing or operating a service.

UNEP-IETC's mandate places emphasis on the management of wastewater and stormwater in urban areas. Urban areas invariably range in population density from a highly dense central districts to lower density areas towards the fringes. On the other hand rural areas may have high density populated sections. The coverage of this Source Book includes the range of technologies that can be applied in these cases. In this way it is hoped that the Source Book has a wider application. The Regional Overviews include Small Island Developing States (SIDS) as these are within the area of interests of UNEP.

The Source Book has been written to cater to the general needs of the above, but has been aimed more particularly to the middle to upper levels of decision-making. Training Materials have been prepared for three levels of decision-making. A one to two day workshop module for top level decision makers (Group A); a 5 to 10 day module for professionals from government and the private sector (Group B), and a half-day to one day seminar for community leaders and the public (Group C).

Training Materials for Group B will cover all aspects of this Source Book, while appropriate selections from the Source Book will constitute Training Materials for Group A and C. Suggested coverage for these groups is indicated below.

Group A

- Costs of wastewater and stormwater mis-management
- Framework for wastewater and stormwater management
- Technology options and selection
- Environmentally sound practices

Group B

- Framework for wastewater and stormwater management
  - Problems facing communities without adequate sanitation
  - Integrated waste management
  - Cross-cutting issues
- Environmentally sound technologies and practices
  - Understanding the basis for sound technologies
  - Wastewater and stormwater collection, treatment, reuse and disposal options
  - Sludge management
  - Technology choice
  - Sustainable scenarios
- Regional overview and information sources
  - Learning from what is happening in other regions

Group C
- Health, hygiene and sanitation
- Community issues and processes
- Technology options and choices
  - Options for local community
  - Examples from other regions and communities
  - Implementation in the local situation

The Source Book brings together experiences and ideas from all regions of the world: Africa, Asia and the Pacific, Europe, Latin America and the Caribbean, and North America. There are vast differences among and within these regions in social, economic and environmental conditions. But there are also many similarities across the regions and over time. The dire sanitation problems in many cities in developing countries were experienced in European cities during the industrial revolution period. People can learn from both avoiding the mistakes and adopting or adapting sound practices applied elsewhere, provided that information is made available. The Source Book aims to facilitate the sharing of information among all regions with the aim of promoting environmentally sound technology practices.

The need for better access to information on sanitation has also been felt by other organisations. UNEP-IETC is collaborating with United Nations Development Programme/World Bank (UNDP/WB) Water and Sanitation Program in producing a complementary Resource Guide on Urban Environmental Sanitation. This Source Book will focus primarily on technology and its practice, while the Resource Guide on the economic, social and institutional issues that affect sound technology practice. UNEP-IETC is also collaborating with WHO Sewage Clearinghouse by providing information on sanitation technology through its maESTro Environmentally Sound Technology data-base (Appendix 3).

The WHO Sewage Clearinghouse is an initiative of UNEP Global Programme of Action (GPA). At the time of printing of this Source Book is developing into a collaborative initiative involving WHO Water Supply and Sanitation Collaborative Council (WSSCC), the International Water Association (IWA) and UNEP GPA under the name Sanitation Connection. UNEP GPA is publishing a brief publication entitled 'Recommendations for Decision Making on Municipal Wastewater - Practical guidance for implementation of the Global Programme of Action for the protection of the marine environment from land based activities'.

Structure of the Source Book

Section 1: Toward a framework for wastewater and stormwater management

Wastewater and stormwater management, though important in itself, needs to be placed in the wider context of improving public health and the environment. It needs to be integrated with municipal solid waste management and hygiene promotion to achieve significant overall public health improvement. It also needs to be practised in the context of physical, geographical, economic, institutional, social and historical context of the community provided with the services. The need for all of these is illustrated by considering the problems facing communities without adequate sanitation.

This section touches on the importance of planning, community participation and sound financial planning and management, and suggests a broad framework for wastewater and stormwater management to achieve long term sustainability. These aspects are discussed in greater detail in the UNDP/WB 'Resource Guide' and UNEP GPA 'Recommendations for Decision Making on Municipal Wastewater'

Section 2: Environmentally Sound Technologies and Practices

The aim of the Sound Practices section is to describe major technology options for collection, treatment, reuse and disposal of wastewater and stormwater. Understanding the basis of the technology is important in helping to make the correct technology choice. This understanding, which is derived from an understanding of the physical, chemical and biological bases of the technology, is emphasised, as well as the corresponding processes taking place in nature. In the latter, the cycling of elements is crucial to maintenance of ecosystems, and is the basis for reuse of wastewater and stormwater, and indeed the basis for environmental sustainability.

The choice of technology amongst the options will be governed by local factors. These include existing technology, facilities and services, availability of land, ability to raise fund and pay for the on-going costs of operation and maintenance, as well as climatic conditions, soil type, and social and cultural settings of the locality where the technology is to be used. These factors are discussed, and a community-scale technology is suggested as one possible model to achieve environmentally sound technologies for long term sustainability.

Section 3: Regional Overviews and Information Sources

For each region an overview is presented in 10 sub-topics with the aim of sharing information on experiences and practices. These sub-topics include those covered in Section 2 and additional topics on Policy and Institutional Framework, Training, Public Education and Financing. There is unavoidable overlap between what is covered in Sections 2 and 3. In discussing a technology practice in a region, there may be a need to describe the technology even though it is a variant of a major option. The appropriateness of the technology in the regional context may also be commented. Not all Regional Overviews follow the sub-topics in a strict manner or order, where there is justifiable reason to highlight, for example, a historical approach or current trends in technology covering several sub-topics.

It is not possible to provide all the information required by decision-makers in a single publication. At the end of each Regional Overview, a list of information sources is provided. The names of institutions that can provide additional information are given, covering international, national and local government agencies, professional and industry associations, tertiary educational institutions and some non-government organisations. Private firms providing technology, equipment or consultant services have not been included.
A number of case studies are provided at the end of each Regional Overview to illustrate sound practices that may have applicability in other regions. It should be noted that sound practices are community and locality specific, and application in other community and locality needs to consider local physical, economic and social conditions.

Appendix 1: Public Health Aspects of Wastewater and Stormwater Management

A primary reason for providing wastewater and stormwater management is to safeguard public health. Decision-makers and community members need to be informed about the health implications of not providing adequate sanitation services. One reason for the lack of priority given to the provision of sanitation services is inadequate appreciation of the health impact of human wastes. A public health crisis (e.g. Surat) usually makes a community aware of the importance of wastewater and stormwater management and a high priority is given to it. Information on the health impact of human wastes is available from the World Health Organization (WHO). An extract has therefore been included.

Appendix 2: Costs of Wastewater and Stormwater Management

When evaluating technology for its affordability it is critical to know what it costs and the costs of alternative technologies. Costs vary with local conditions. The Source Book provides information on relative costs of the major technology options.

Appendix 3:maESTro and UNEP Contact Information

The United Nations Environment Programme (UNEP) has regional offices as well as other centres that can facilitate contact with organisation active in wastewater and stormwater management. This appendix provides contact information for the relevant UNEP offices.
Information on IETC's maESTro data base on environmentally sound technologies is provided to facilitate contact with organisations providing these technologies.

Bibliography

The Source Book contains references that are cited in the book. Lists of these references are provided at the end of the appropriate sections. These references may be consulted by readers if they are interested in obtaining further information on the subject cited. The Bibliography included here contains a bibliography of selected recent items that may be useful to decision makers and others working in wastewater and stormwater management. It is sourced primarily from international organisations who have worked in these areas for some time.

Glossary

As a reference for terms used in the book, a glossary of words and phrases relevant to wastewater and stormwater is included.

How to use this book

This book is intended to be used in a number of ways by using information from a combination of sections or sub-sections. To gain an appreciation of the problem of sanitation, Section 1 and Appendix 1 provide a broad overview. This information may be what community leaders need to appreciate to consult with community members on priority to be given to wastewater and stormwater management. For a professional who wishes to familiarise with major technology options in sewerage, Section 2 (3) provides this overview. This can be combined with relevant sections in the Regional Overviews (Section 3 (2)). On the other hand an urban manager in a South American city may want to read the whole of the South American Regional Overview, and Section 2 (3) if low cost sewerage is being considered. If further information is required the list of information sources at the end of the Regional Overview can be consulted.

The Training Materials produced with the Source Book cater to three levels of decision-making (see above under Purpose and Intended Audience)

The Source Book, as compared to a technical manual

The Source Book is not intended to be a technical manual. It does not provide technical details or design procedures. Many excellent technical manuals and handbooks are available. This Source Book lists some of these in the Lists of References. Furthermore the Information Sources listed at the end of each Regional Overview can provide further information (e.g. Professional Associations). Similarly the Source Book does not provide detailed costs for the technologies or cost-benefit analysis for each technology option. Such analyses should be done in the context of a particular local application.

The Source Book, however, provides a broad overview of technology options, which can achieve protection of public health and the environment. Furthermore it points to practices that can be environmentally and financially sustainable. These are because resources in the wastewater and stormwater are recycled rather than disposed, and that the technology is acceptable and affordable to the community it serves.

Note on the coverage of stormwater management: Wastewater and stormwater are inevitably intertwined, because wastewater may be disposed into stormwater drainage, wastewater and stormwater may be collected in the same sewer, and inevitably there is cross-connections even when wastewater and stormwater are separately collected. The treatment principles for stormwater are similar to those for wastewater. The subject of stormwater management is in itself very wide ranging, from estimating run-off from rainfall or storm events to control of flooding. Coverage of stormwater management in the Source Book has been confined to stormwater generated on-site and where stormwater and wastewater are collected or treated together. Basin wide stormwater management and control of flooding (stormwater diversion canals, floodgates) are not specifically covered. Nonetheless if the same technologies presented in this Source Book for stormwater collection, treatment, reuse and disposal are applied on a river basin wide basis, then significant contribution to preventing flooding will be achieved.

Section 1
Toward a framework for wastewater and stormwater management

This section develops a framework for wastewater and stormwater management by first describing the problems facing communities without adequate sanitation. This is to provide a background for the type of management that is required to address the problems. The concept of integrated waste management is then introduced and the wider issues, besides those of technology, are discussed. A framework for wastewater and stormwater management is then outlined.

1. Problems facing communities without adequate sanitation

Inadequate sanitation facing a substantial proportion of the world's population is well documented (recent WSSCC figures indicate that we are falling behind in providing adequate sanitation world-wide see http://www.wsscc.org/vision21/wwf/v21flyer.html for details). The overview on each region in the Source Book provides a summary of conditions in the regions. Many of those without sanitation are in rapidly growing cities in developing countries, affecting the poor in general, though the situation is not confined to these cases. Following the considerable effort during the UN Decade of Water and Sanitation (1981 – 1990) much discussion and analyses have been undertaken to find the causes for the lack of success in providing sanitation for all, and many ideas have been put forward to overcome the problems. The Water Supply and Sanitation Collaborative Council (WSSCC), for example, has prepared thematic papers on the subject (WSSCC, 1999a) in preparation for developing a framework for future action, Vision 21: A shared vision for water supply, sanitation and hygiene (WSSCC, 1999b).

The issues involved in providing sanitation for much of the world's population are complex. It is difficult to cover the technical, social, economic and environmental dimensions in a brief space. It is also difficult to generalise the setting or circumstances of these communities. Each has its own physical, cultural and political setting. Nonetheless it is desirable to portray the physical setting facing communities without adequate sanitation so that we can gain a perspective of how the problems develop, and how communities have responded to these problems.

In general these communities are located in an environment which has a relatively high population density. Water supply may or may not be adequate in either quality or quantity. In cases where water is supplied through pipes, there are not the corresponding pipes for removing the wastewater generated. The wastewater is simply allowed to flow by gravity through the natural drainage of the landscape ending in low lying areas, water courses, lakes, groundwater aquifers or the sea. The natural drainage carries stormwater run-off during rainfall events, and during flood events stormwater mixes with wastewater, and polluted water is spread over a much wider area than the drains. In addition solid waste is also generally dumped into the drains or natural water courses resulting in flooding at lower rainfall events. Water-borne diseases are therefore endemic in these communities. The environmental conditions of the area are degraded, because water containing decaying organic substances from sewage and garbage give foul odour, the water is depleted of oxygen and is putrid. Groundwater in the area is also generally polluted, because of the infiltration of polluted water to the groundwater aquifer. The general physical environment is as illustrated in Figure 1.1.

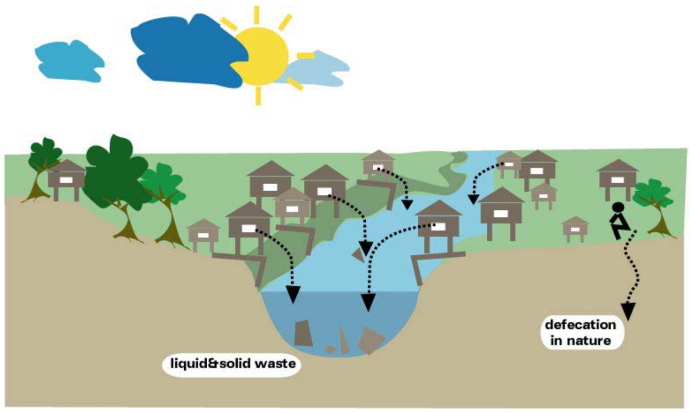


Figure 1.1: Urban settlement with high population density, sewage disposed to drains, pollution of drains, streams, river/sea and groundwater

If the population density is very low, the environment has the capacity to absorb the wastes generated and environmental degradation is negligible. Water quality of streams, rivers and groundwater in this environment is generally excellent. Figure 1.2 illustrates a very small population in a natural forest setting. The natural processes involved in the assimilation of the wastes are elaborated in Section 2 (2.2).

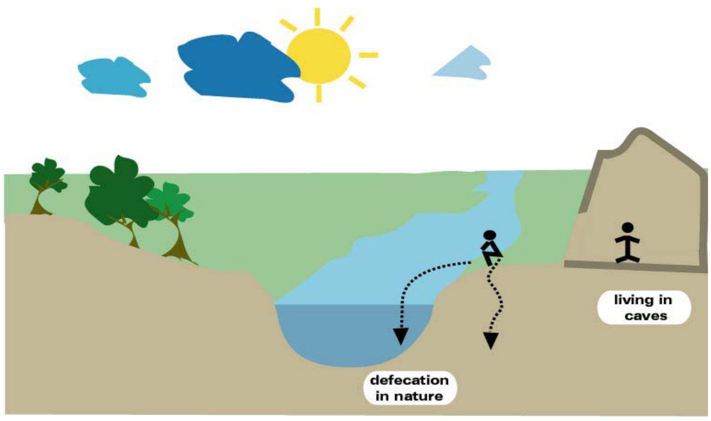


Figure 1.2: Small settlement in a natural forest

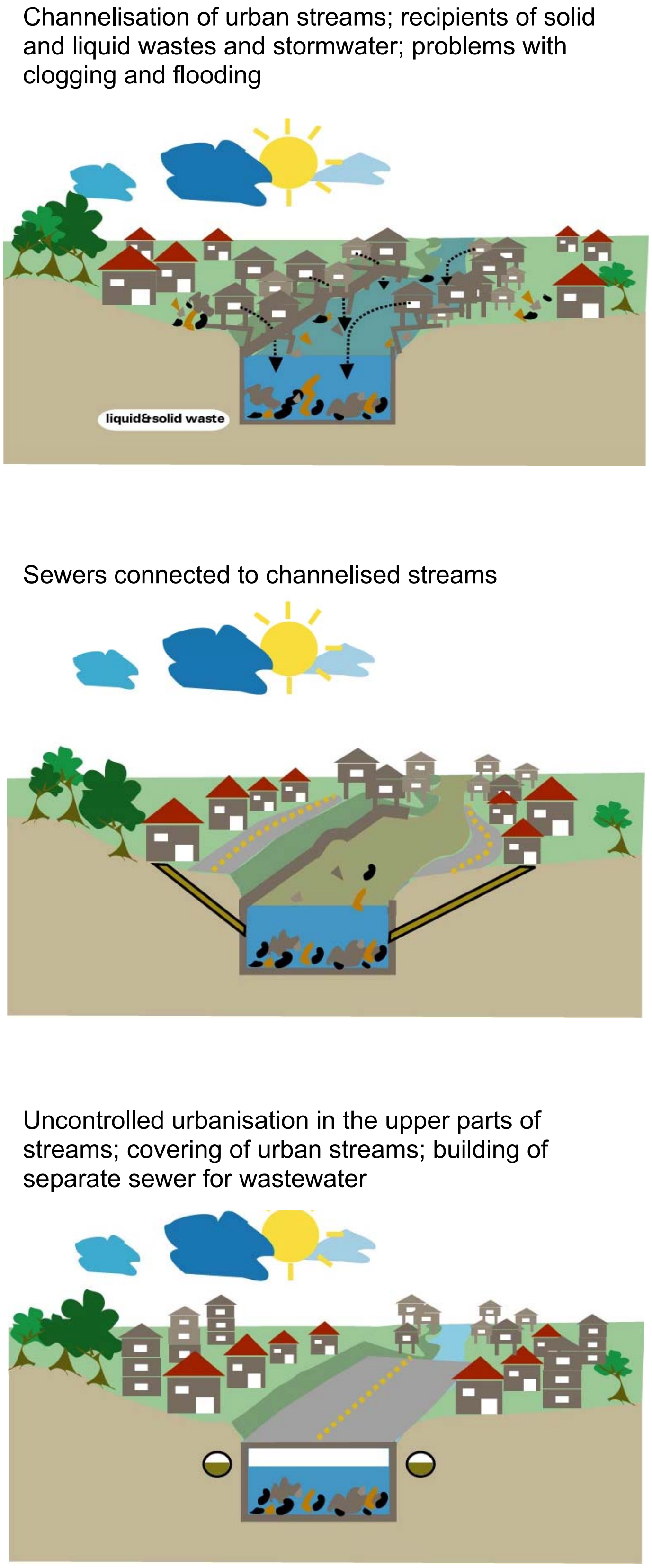


Figure 1.3: Sewerage system to convey wastewater and stormwater away from communities

When the amount of wastes disposed to the environment increases with the increase in settlement population, the capacity of the receiving environment to assimilate the wastes is exceeded and degradation of the environment takes place (Figure 1.1). Communities have responded in different ways to the public health problem and environmental degradation that are created. Even though there have been numerous ways in which the problem has been addressed, we may generalise these in terms of stages depicted in Figures 1.3 – 1.5.

Because of the importance of dealing with health problems caused by wastewater within the community, wastewater is transported away from the community. This is done by improving drainage, while still conveying both wastewater and stormwater through the same drains. Measures to reduce the incidence of flooding are usually applied, by for example, deepening drainage channels, preventing solid wastes from being dumped into drains, and covering of the drains represents the first attempt to provide a sewerage system (Figure 1.3). In this way wastewater and the inherent human pathogens in it are removed from the community as a source of public health threat.

Environmental degradation of the receiving water still continues. If the wastewater is disposed to a river the water will affect people using it for bathing and washing, and downstream communities may withdraw the water for drinking purposes. The amenity value of the river for recreational purposes, for fishing, agriculture and industry is devalued. The classification of rivers is a good illustration of how the quality of a river is determined by its pollution load (Table 1.1).

Table 1.1: River pollution classification

Class	Description	DO. & BOD*	Characteristics
Class I	Unpolluted or recovered from pollution	BOD < 3 mg/L	No toxic or suspended discharges which affect the river
Class II	Doubtful quality and needing improvement	BOD > 3 mg/L, toxic and reduced DO in dry flow times	Toxic and suspended discharges occur but have no major effect on biota
Class III	Poor quality, improvement is a matter of some urgency	DO < 50% for considerable periods	River changed in character, suspected of being actively toxic. Subject to serious complaint
Class IV	Grossly polluted rivers	BOD > 12 mg/L, completely deoxygenated	Incapable of supporting fish life, grossly offensive

*DO = dissolved oxygen; BOD = biochemical oxygen demand
(based on National Water Council (UK) classification, 1970)

Biochemical Oxygen Demand (BOD)

In Table 1.1 the river water pollution load is indicated by its biochemical oxygen demand (BOD) concentration. BOD is a measure of the amount of biodegradable organic substances in the water. As naturally occurring bacteria consume these organic substances they take up oxygen from the water for respiration, while converting the substances into energy and materials for growth. On average each person produces about 60 g of BOD in faecal and other materials. This is equivalent to 60,000 mg of BOD. Depending on the volume of water used to convey the faecal materials, the concentration of the BOD in the wastewater varies. For example if the total water usage per person is 200 L per day, then the resulting wastewater will have a BOD concentration of 300 mg/L. Upon discharge to a river the concentration is further diluted by the river water. The BOD of industrial wastewaters can be very high (e.g. abattoir, paper mill).

The river pollution classification (Table 1.1) provides an illustration of the ability of the environment (here the river) to cope with small waste discharges of organic wastes. Small

discharges of BOD are diluted by the river water to low levels. If the concentration of BOD in the river water is less than 3 mg/L the river remains 'unpolluted'. The oxygen uptake by bacteria, as they consume the organic wastes, is replenished by the continuous transfer of oxygen from the atmosphere to the water. The dissolved oxygen (DO) concentration in the water remains high. This simple process explains the reason why a stream in an undisturbed forest remains clean despite the natural organic wastes produced by animals in the forest. Other physical, chemical and biological processes take place which help in the ability of nature to purify wastes. These are elaborated in Section 2 (2.2).
On the hand the river pollution classification shows that it does not take much for an unpolluted river (class I) to become a grossly polluted river (class IV). When the BOD concentration in the river water is greater than 12 mg/L, the transfer of oxygen from the atmosphere cannot replenish the oxygen demand and the water becomes completely deoxygenated. It is incapable of supporting fish life. The water is dominated by bacteria that thrive on the organic wastes but able to extract oxygen chemically from substances like sulphates in the wastes. Gases such as hydrogen sulphide (rotten egg gas) and methane are generated by these bacteria. Foul odours are the result, and the appearance of the water is grey black with bubbles frothing up.

To prevent degradation of the receiving environment wastewater needs to be treated. This treatment is usually carried out at the point of discharge, also called 'end of pipe' treatment (Figure 1.4). Treatment consists of removing solids from the wastewater and reducing its BOD. The degree of treatment that is required is dependent on the capacity of the receiving environment to assimilate the remaining organic wastes.

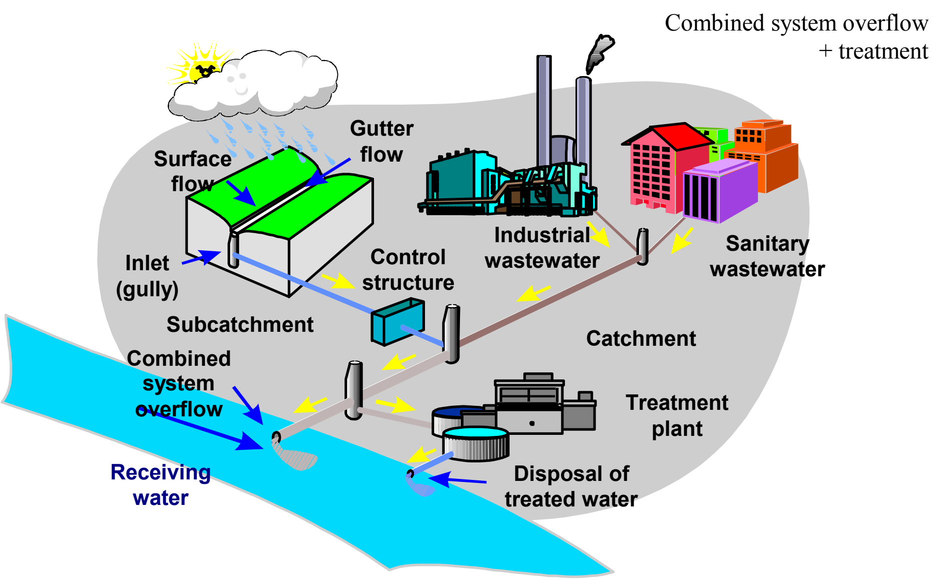
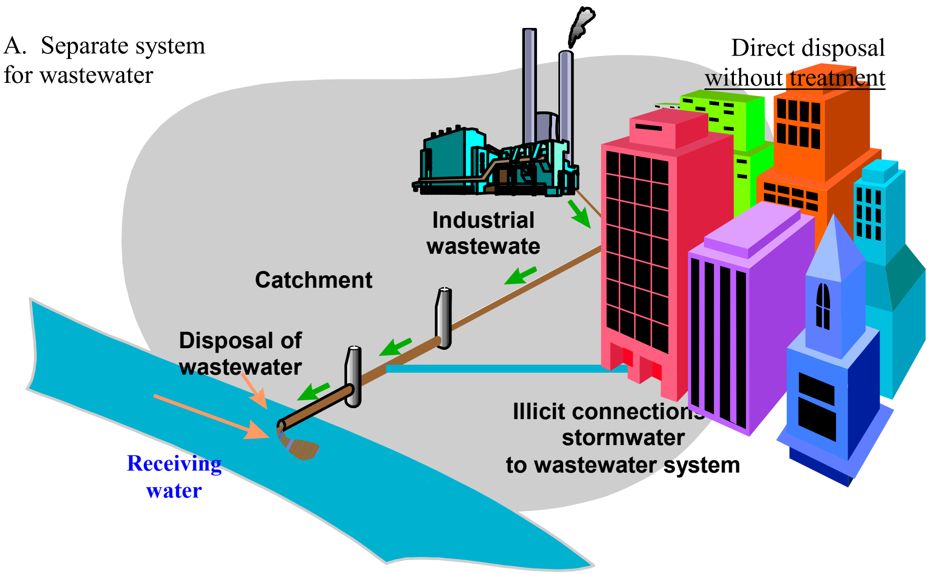


Figure 1.4: End of pipe treatment of wastewater prior to discharge to the environment

Because the wastewater treatment facility is generally designed for dry-weather flow, its capacity is exceeded in wet weather. Treatment efficiency drops during wet weather, and in high rainfall events a significant volume of combined wastewater and stormwater is not effectively treated. To overcome the problem of wet-weather flow, and recognising that stormwater may not be as contaminated as wastewater, separate collection of wastewater and stormwater have been implemented (Figure 1.5), with stormwater treated only to remove gross solids.



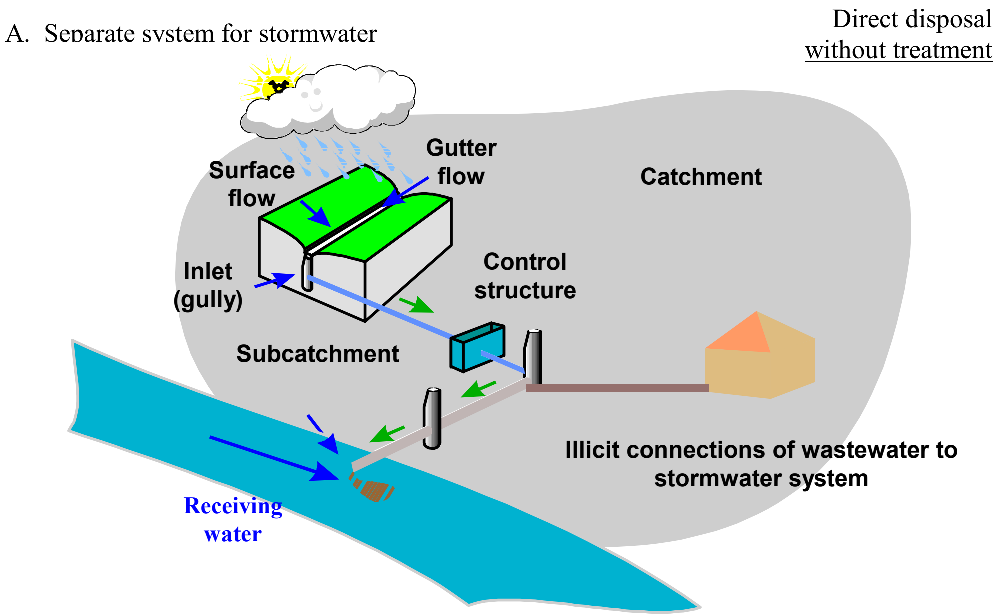
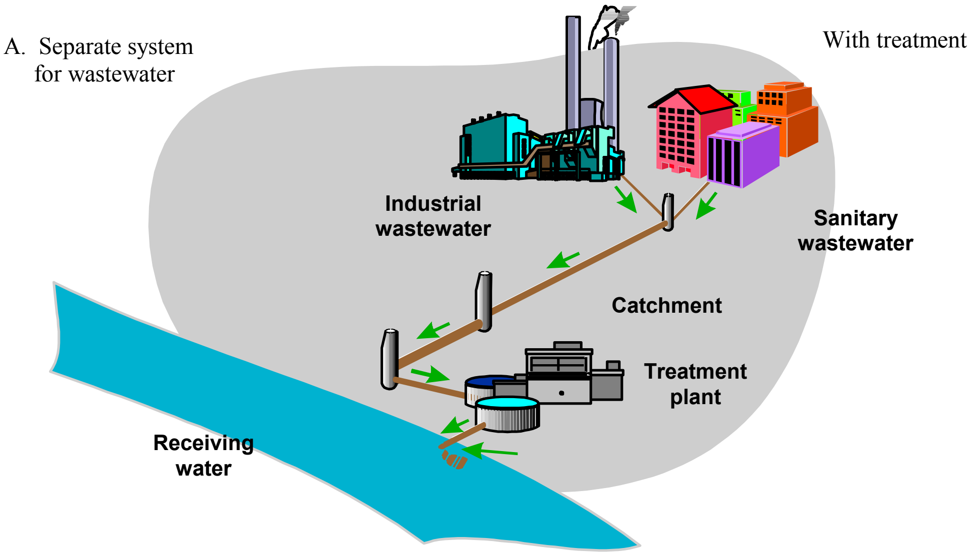


Figure 1.5: Separate collection of wastewater and stormwater

If wastewater is collected separately, there is no reason why stormwater should be collected in pipes. A recent trend is for stormwater to be channelled through the landscape's natural drainage, and for the drains to be landscaped to resemble a more natural landscape with vegetation in their flood plain (Figure 1.6). In addition there is the desire to reuse the treated wastewater with its nutrients for purposes such as irrigation of parks and gardens.



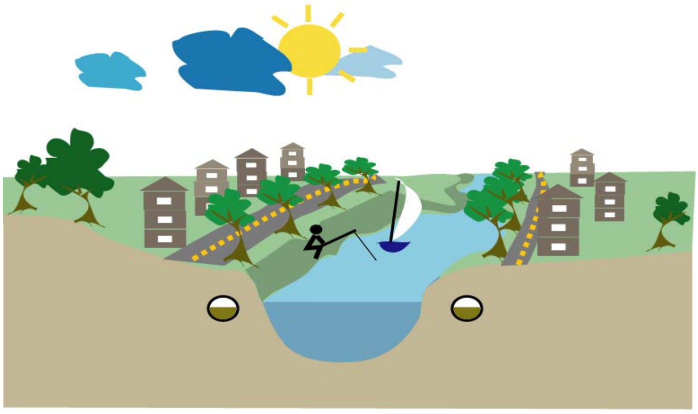


Figure 1.6: Separate collection of wastewater for end of pipe treatment, and stormwater allowed to flow through natural waterways and their flood plain. Reuse of treated wastewater for irrigation purposes.

It is worth noting that the severe sanitation problems currently facing many cities in developing countries were experienced in Europe as recently as at the end of the nineteenth century, with epidemics of water borne diseases occurring in London then. The section of river Thames passing through London was grossly polluted until the 1970s. Sewage discharges to the river were treated to reduce BOD concentration and raise DO to enable fish to return. The history of wastewater and stormwater management in Europe is described in greater detail in the Regional Overview for this region.

While the stages of development of sewerage and drainage portrayed above are generalisation of observation in many cities, they are by no means the only way to overcome the problems of sanitation. Various options are described in Section 2 together with their advantages and disadvantages, and a general strategy for selecting the most appropriate option for a particular case suggested.

2. Integrated waste management

The description of problems facing communities without adequate sanitation above shows the importance of addressing the problems in an integrated manner. Simply solving the problem of wastewater without taking into account of solid wastes and stormwater will not achieve sufficient sanitation improvement to protect public health and the environment. UNEP IETC has published an International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management, which provides guidance on the selection of technology for the management of solid waste. The present UNEP IETC Source Book complements this publication, and is intended to provide the means to achieve the integrated approach.

In discussing integrated waste management we need also to consider solid wastes and wastewater produced by industry. In many instances these may not differ in characteristics from domestic wastes, consisting primarily of biodegradable organic substances. Industry, however, produces numerous types of wastes which may be toxic to bacteria that are utilised to treat domestic wastewater. The practice in many communities is for industrial wastes to be disposed with domestic wastes.

One principle that logically emerges from adopting an integrated approach to waste management is that different types of waste should not be mixed (Figure 1.7). Solid wastes should not be dumped into stormwater drains, but should be collected, recycled, reused, or treated and disposed separately. Dumping of solid wastes in stormwater drains will not only restrict the flow of stormwater, they contaminate stormwater. Treatment of the stormwater will involve separating the solids and other contaminants from the water. Similarly industrial wastes should be treated separately, and industrial wastewater should be pre-treated if they are to be discharged to the sewer.

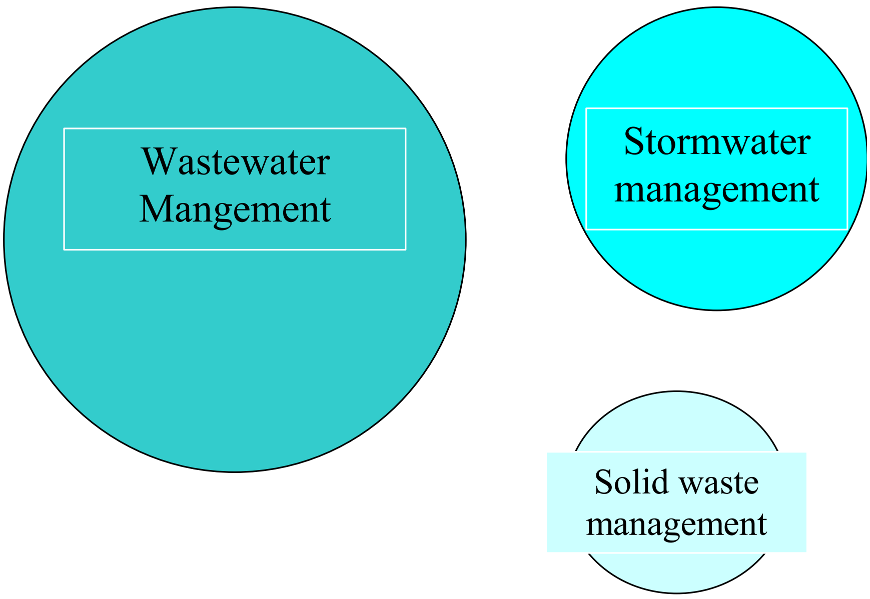


Figure 1.7a: Non-integrated waste management. Each waste is managed individually without coordination.

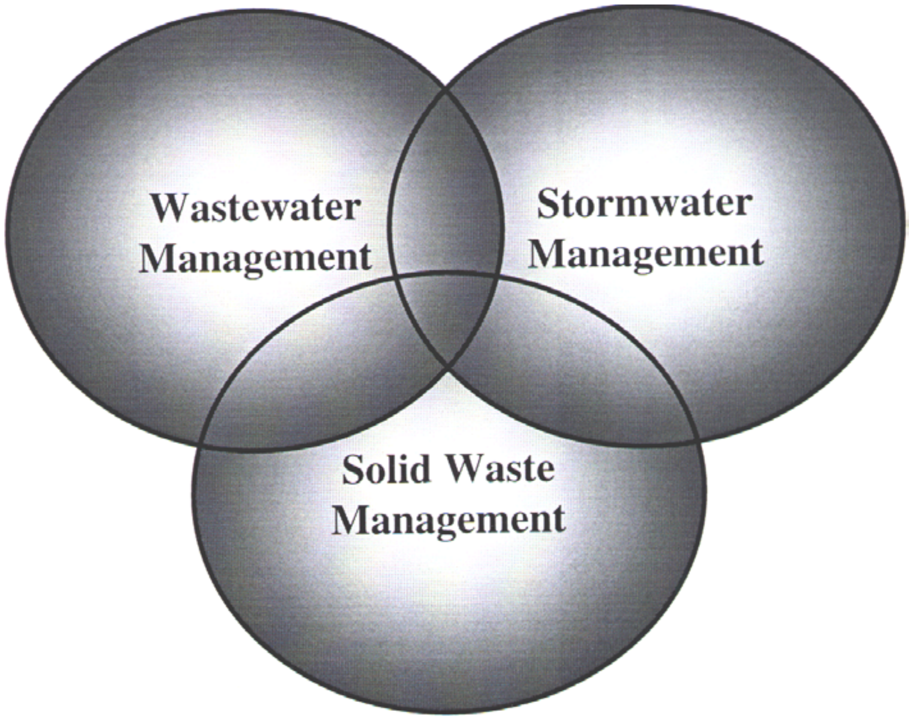


Figure 1.7b: Integrated waste management. All wastes should be considered together to achieve environmental and public health improvement. Wastes should be separately collected and managed

A useful tool that can help towards achieving integrated waste management is the waste management hierarchy. It has been used to direct waste management towards achieving environmentally sound practice. The waste management hierarchy in its most general form is shown in Table 1.2. In using this tool for waste management we systematically go down the list to see if step 1 (Prevent or reduce waste generation) can be implemented, before considering the next step (2) and so on. Only when steps (1) to (5) have been fully considered that we consider disposal of the waste (step 6).

Table 1.2: The waste management hierarchy

1	Prevent or reduce waste generation
2	Reduce the toxicity or negative impact of the waste
3	Recycle waste in its current form
4	Reuse waste after further processing
5	Treat waste before disposal
6	Dispose in an environmentally sound manner

We cannot prevent the production of human excreta or stormwater, but we can prevent other materials from being disposed with human excreta, or solid waste with stormwater. We can use less water to achieve the same purpose (e.g. flushing toilet) and hence produce less wastewater. We can avoid toxicity of wastewater by preventing toxic household or industrial wastes to be disposed with biodegradable organic wastes. A reuse example is the use of urine as a liquid fertiliser, while composting can convert human excreta into a soil conditioner. Other examples will be discussed in Section 2, but it should be recognised that all waste management practices have costs as well as benefits. The application of the waste management hierarchy therefore needs to consider economics as well as other factors (e.g. some culture may not allow reuse of human wastes).

3. Cross-cutting issues

From examining how sanitation problems develop in a community (Figure 1.1 to 1.6) it becomes obvious that they are related to population density relative to the ability of the environment to cope with the wastes generated, and the ability of the community to respond to the problems that arise. Thus besides the public health and environmental aspects that we have discussed, there are the social and institutional dimensions that have to be taken into account. These refer to the way communities organise themselves to manage their common affairs, such as arranging collection of household solid wastes, laying of sewer pipes, and financing these activities. Each community has generally developed means of carrying out these tasks, which may be unique to a particular community or communities in a region. The institutional arrangements in a community evolve with time to meet changes in culture and technology, and may or may not cope with external changes. One of the latter is rapid urbanisation, and it is generally in such a situation of rapid population growth that severe sanitation problems occur.

The issues associated with how communities manage their common endeavour, which in our case is managing wastewater and stormwater, are termed ‘cross-cutting’ issues. These issues are elaborated further and addressed in a complementary publication by UNEP GPA ‘Recommendations for decision making on municipal wastewater” as well as the United Nations Development Programme/World Bank (UNDP/WB) publication ‘Resource Guide in Urban Environmental Sanitation’ published concurrently as the present UNEP-IETC Source Book. Readers should refer to the Resource Guide, which cover the three areas of wastewater, stormwater, and urban solid wastes, for a more detailed discussion of the issues and suggested strategy to address these issues.

The major issues are depicted in Figure 1.8.

Figure 1.8: Major cross cutting issues of planning, community participation and finance

Settlement planning

Planning appears to be a major and key issue for a community to address. Ideally settlements should be planned ahead of their occupation. Areas should be set aside for treatment and disposal of solid wastes which cannot be recycled or reused. Easement should be provided in the plan if wastewater is to be collected through a sewerage system, or if on-site treatment is chosen, lot sizes should be able to adequately accommodate the treatment system. Planning should also take into account the natural drainage of the landscape to enable stormwater run-off to flow freely by gravity and minimise flooding. Water reuse should also be carefully planned. Generally a sufficient area must be set aside for water reuse, which can take the form of water for agriculture, aquaculture, tree plantation or for irrigation of public parks and gardens.

New approaches to planning to achieve long-term resource sustainability for wastewater and stormwater management should be considered in a planning process. Stormwater infiltration at source to reduce heavy downstream run-off is an example. Water conservation measures can reduce wastewater volume, and dry sanitation where appropriate merits consideration.

In a rapid urbanisation process and with illegal settlements occurring, the situation is far from ideal. Decisions have to be made based on the existing far-from-ideal situation. In most cases no action is taken until the legal status of the land occupation is clarified, and this can take quite some time. In the meantime temporary measures need to be taken to provide sanitation services to prevent disease outbreak and downstream environmental problems. In the first instance piped water may be provided from standpipes. If no corresponding measure is taken to provide for wastewater collection, then invariably poor sanitation conditions result. This illustrates an important point in planning and integrated waste management that when water is provided, wastewater disposal should be considered at the same time, because provision of water means wastewater is simultaneously generated. Disposal of the wastewater into stormwater drains is clearly not satisfactory as mentioned earlier. The problems arising from the provision of water may be negated by the problems caused by the wastewater.

Community participation and hygiene promotion

Much has been said about the need to involve the whole community in provision of sanitation services to ensure that any service that is provided is what the community wants. This will help ensure the viability of the service and its long term sustainability. The need to involve women has been emphasised, because women are generally responsible for the day to day management of wastes at the household level. How far community participation can be implemented depends on the social, cultural and political practices within the community.

The decisions taken by a community are influenced by its knowledge base. One aspect that may be lacking is the awareness of the relationship between illnesses and lack of hygiene and sanitation. This may be reflected in the low priority given to provision of sanitation services. Promotion of hygiene is therefore an important issue that has to be addressed. The promotion materials should include not only the relationship between health and sanitation services, but also the correct choice of sanitation hardware, and in its maintenance and operation. It has been argued that sound hygiene practices, even with inadequate sanitation provision can improve health outcome. It is, however, preferable to have sound hygiene practices go hand in hand with environmentally sound sanitation hardware.

Financing of sanitation services and cost recovery

Sanitation services require investment and continuing costs of operation and maintenance. The level of investment is dependent on the technology that is chosen. The technology also determines the costs associated with its operation and maintenance. A community may be able to provide in-kind contribution such as labour towards the construction of a wastewater collection system. With a simple on-site wastewater system the community may be able to do most of its construction. Knowledge of technology options is therefore essential to a community to decide which one to choose, because in the end they have to pay for both the investment and operating costs if the service is to be sustainable in the long term. Technology options are presented in Section 2.

4. Framework for wastewater and stormwater management

Integrated waste management requires the involvement of all stakeholders, and these include policy makers (governments), investors (governments/private sector companies), managers (public and private sectors) and users (communities/community organisations). Figure 1.9 illustrates the relationship between the major stakeholders. It is important to appreciate the jurisdiction and responsibility of each to achieve the coordination that is vital in achieving the integrated approach.

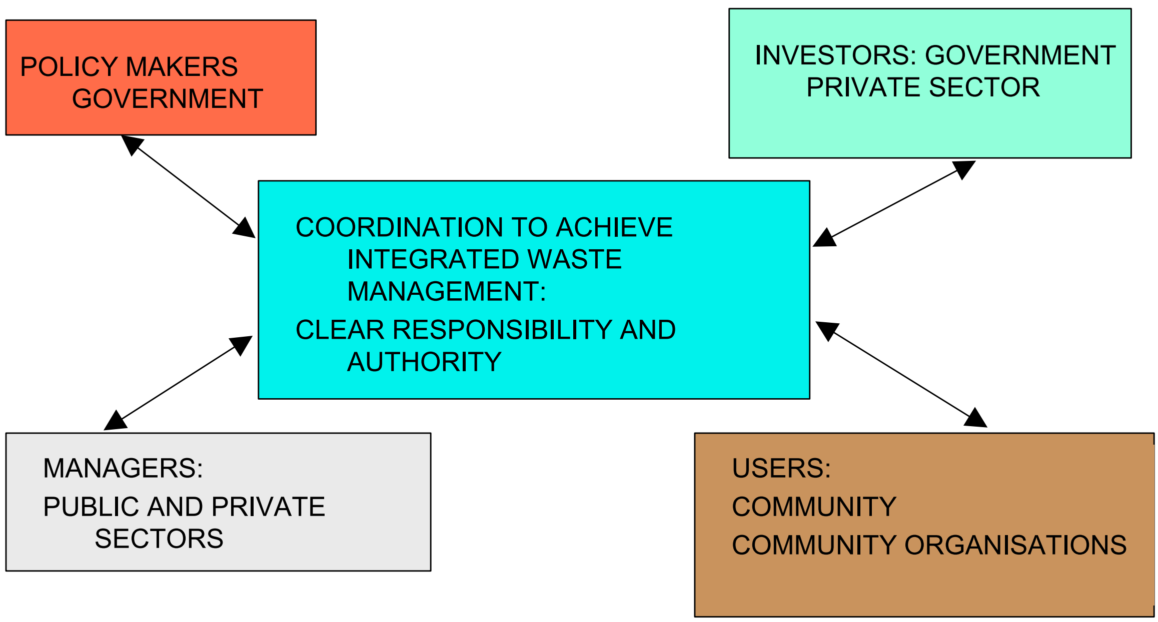


Figure 1.9: Relationship between major stakeholders in integrated waste management.

Governments have generally final jurisdiction and responsibility in waste management by setting overall policy, whether they are involved in performing the management functions or not. Many government departments play crucial roles in the management of wastewater and stormwater. Public health departments have jurisdiction over the maintenance of public health. In an intregated system a public health department has responsibilities in monitoring, inspection and enforcement of public health and in general hygiene promotion. Public works departments have jurisdiction over large infrastructure projects in wastewater and stormwater.

They have the responsibility for operating and maintaining centrally operated wastewater/stormwater systems, and overview the systems operated by private contractors.

Often environmental departments assist in providing policy input in waste management as wastes can seriously impact on the environment. They formally assess environmental impacts of major infrastructure projects. These departments can play a major role in the coordination of major stakeholders in an integrated waste management system. Often the above jurisdiction and responsibilities are devolved to provincial or municipal governments with the central government setting general policies and planning parameters. With many stakeholders involved, the crucial factor is the coordination of all the major stakeholders. Responsibility and authority, including final responsibility for decision making, need to be clearly spelt out.

Private sector companies provide a range of services ranging from being contractors to government in conducting feasibility studies, community consultation, drawing master plans for wastewater and stormwater infrastructure, to constructing the infrastructure and operating wastewater and stormwater facilities. Private sector companies operate with the aim of making a profit. Unlike governments they do not have direct responsibility in maintaining public health or quality of the environment. Pressures on government to reduce taxes have resulted in privatisation of services such as wastewater and stormwater management. The stages in privatisation are illustrated in Figure 1.10.

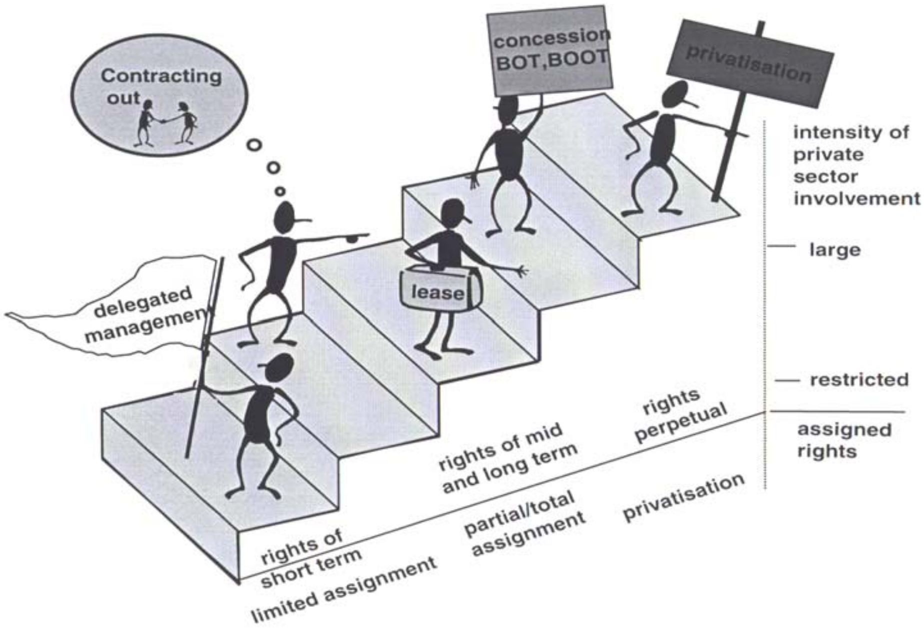


Figure 1.10: Various phases in privatisation of waste management services.

The importance of community involvement as users of wastewater and stormwater management services has been pointed out in (3b) above. This is to ensure that the services are what the community desires and is able to pay for to ensure long-term sustainability of the services. Community participation can be facilitated by community based organisations or non-government organisations in the area.

Communities without legal status of land they occupy in rapidly growing peri-urban areas present a special problem. These communities usually require urgent sanitation services because of serious local public health threat as well as downstream impacts of the wastewater. These communities have inadequate resources and may not be able to afford any form of paying sanitation service. Because of the threat to public health generally and downstream impact of wastewater from these communities, a case can be made for governments to provide the very basic sanitation services. The involvement of the informal sector already operating in these communities is crucial to ensure that the services are what the community wants and willing to contribute (e.g. labour and cash towards operation and maintenance).

Integrated waste management involving all stakeholders and coordination of all aspects of waste management should provide the basis for long term sustainability of wastewater and stormwater services. Factors which need to be taken into account include: characteristics of the wastes, how communities want them to be collected, treated, reused or disposed, policy setting, information available to the community, public education, training, method of financing and cost recovery. Note that governments may be able to control or restrict certain products that have potential to generate wastes from entering the country. The Source Book includes a section on these, as well as a description of the experiences and practices in each of the regions.

Section 2
Environmentally Sound Technologies and Practices

1. Overview of the Sound Technologies and Practices section

Technologies which are environmentally sound are technologies which help protect the quality of the environment. It may be argued that technologies used to manage wastewater and stormwater are inherently environmental technologies, because without these technologies the pollutants in wastewater and stormwater will negatively affect the environment (Section 1). Some of these technologies may utilise less energy than others, produce less air pollution or hazardous sludge, or more suited to wastewater and sludge reuse. Hence some of these technologies are more sustainable. The application of a technology is dependent on local physical factors of land availability, its topography, climate, soil, availability of energy and existing land uses. Sound technology practice is therefore dependent on being able to fit the technology to the local conditions.

Sound practice is also dependent on the context of the local community where the technology is to be applied. Long term sustainability is a function of community resources (funds, skills) to afford the technology and its willingness to pay for the technology and its operation. Sound practices are therefore practices which fit into the environmental, economic, social, cultural and institutional setting of the community.

In this Section wastewater and stormwater characteristics are described to set the context for technologies that need to be used to manage the pollutants they contain. The description is also meant to indicate the resources that are contained in human excreta, and therefore its potential for reuse. Technologies for collection, treatment, reuse and disposal are then described, so that options for the different local environmental, economic and social contexts described above can be evaluated. The description is not meant to be exhaustive, but to enable the scientific basis of the technologies to be understood. The relationship between processes in engineered systems and natural purification processes is also presented, so that simple engineered systems that are more akin to natural systems can be appreciated. Sludge is produced from treatment systems, and a section is devoted to its characteristics, treatment, reuse and disposal. Finally sound technology practices are reviewed in the context of environmental, economic and social conditions of a community.

2. Wastewater and stormwater characteristics (Topic a)

Household wastewater derives from a number of sources (Figure 2.1). Wastewater from the toilet is termed 'blackwater'. It has a high content of solids and contributes a significant amount of nutrients (nitrogen, N and phosphorus, P). Blackwater can be further separated into faecal materials and urine. Each person on average excretes about 4 kg N and 0.4 kg P in urine, and 0.55 kg N and 0.18 kg P in faeces per year. In Sweden it has been estimated that the nutrient value of urine from the total population is equivalent to 15 – 20 % of chemical fertiliser use in 1993 (Esrey et al., 1998). Table 2.1 shows characteristics of human excreta and a comparison with nutrient contents of plant matter to indicate its value as a soil conditioner and fertiliser.

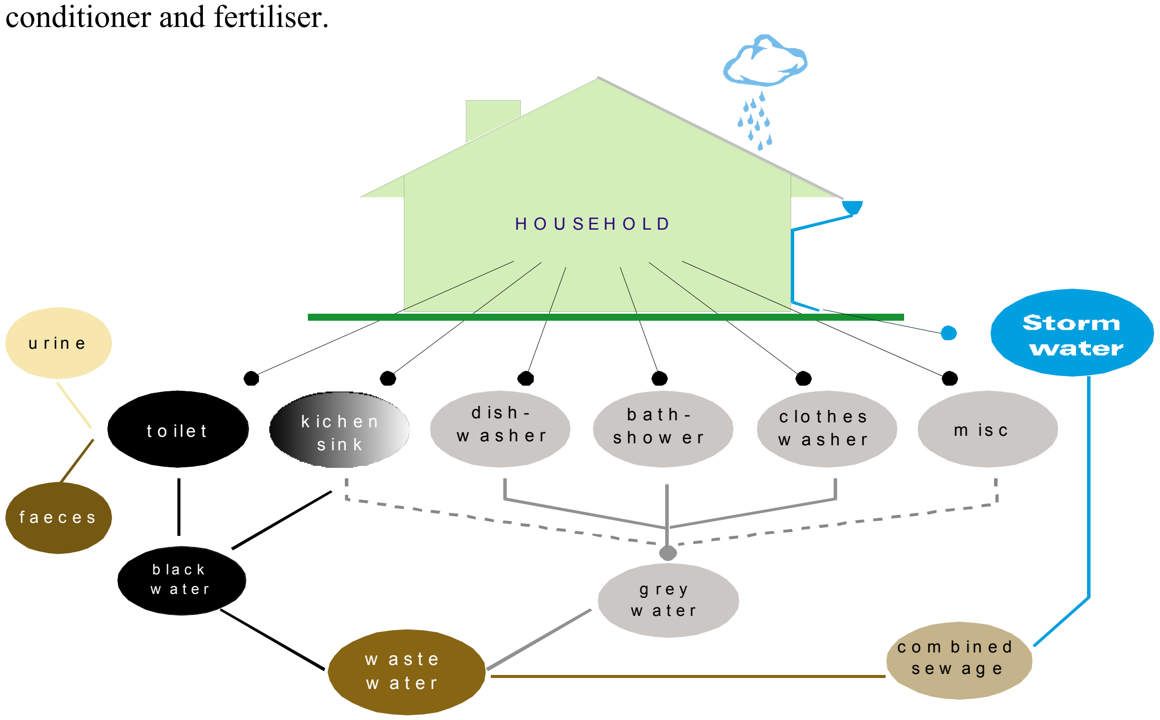


Figure 2.1: Sources of household wastewater, showing wastewater from toilet, kitchen, bathroom, laundry and others

Greywater consists of water from washing of clothes, from bathing/showering and from the kitchen. The latter may have a high content of solids and grease, and depending on its intended reuse/treatment or disposal can be combined with toilet wastes and form the blackwater. Both greywater and blackwater may contain human pathogens, though concentrations are generally higher in blackwater.

The volume of wastewater and concentration of pollutants produced depend on the method of anal cleaning, volume of water used and water conservation measures. Dry anal cleaning results in higher solids and fibre content. The use of dry pit latrines and the practice of water conservation produce low volume and high concentration wastewater, while use of flushing toilets results in higher wastewater volumes and lower concentrations. The characteristics of wastewater in the Regions are described in the Regional Overviews under Topic a.

Table 2.1: Human excreta – per capita quantities and their resource value (Strauss, 1985)

	Faeces	Urine	Excreta
Quantity and consistency			
Gram/capita/day (wet)	250	1,200	1,450
Gram/capita/day (dry)	50	60	110
Chemical composition (% of dry solids)			
Organic matter	92	75	83
Carbon C	48	13	29
Nitrogen N	4-7	14-18	9-12
Phosphorus (as P_2O_5)	4	3.7	3.8
Potassium (as K_2O)	1.6	3.7	2.7

Comparison with other wastes (% of dry solids)	N	P_2O_5	K_2O
Human excreta	9-12	3.8	2.7
Plant matter	1-11	0.5-2.8	1.1-11
Pig manure	4-6	3-4	2.5-3
Cow manure	2.5	1.8	1.4

The flow of wastewater is generally variable with peak flows coinciding with high household activities in the morning and evening, while in the night minimal flow occurs. Pollutant loads vary in a similar manner.

Stormwater in a community settlement is produced from house roofs, paved areas and from roads during rainfall events. In addition stormwater is produced from the catchment of a stream or river upstream of the community settlement. The amount of stormwater is therefore related to the amount of rainfall precipitation, and the nature of surfaces, with impervious surfaces producing more run-off. During a storm event the peakflow is higher and duration shorter with an impervious surface, while the peakflow is lower and duration longer with a vegetated surface (Figure 2.2).

Stormwater run-off may contain as much solids as household wastewater depending on the debris and pollutants in the path of the stormwater run-off, although in general the pollutant load of stormwater is lower than that of wastewater. Table 2.2 shows a comparison of urban stormwater sources and untreated sewage in North America.

Table 2.2: Comparison of the characteristics of stormwater sources and untreated sewage (Novotny and Olem, 1994; Novotny, 1995)

Type of wastewater	BOD_5 (mg/L)	Suspended solids (mg/L)	Total N (mg/L)	Total P (mg/L)	Total Coliforms (MPN/100mL)
Urban stormwater	10-250 (30)	3-11,000 (650)	3-10	0.2-1.7 (0.6)	10^3-10^8
Construction site run-off	NA	10,000-40,000	NA	NA	NA
Combined sewer overflows	60-200	100-1,100	3-24	1-11	10^5-10^7
Light industrial area	8-12	45-375	0.2-1.1	NA	10
Roof run-off	3-8	12-216	0.5-4	NA	10^2
Untreated sewage	(160)	(235)	(35)	(10)	10^7-10^9
Wastewater treatment plant effluent (secondary treatment)	(20)	(20)	(30)	(10)	10^4-10^6

Figures in brackets = mean values; NA = not available; MPN = most probable number

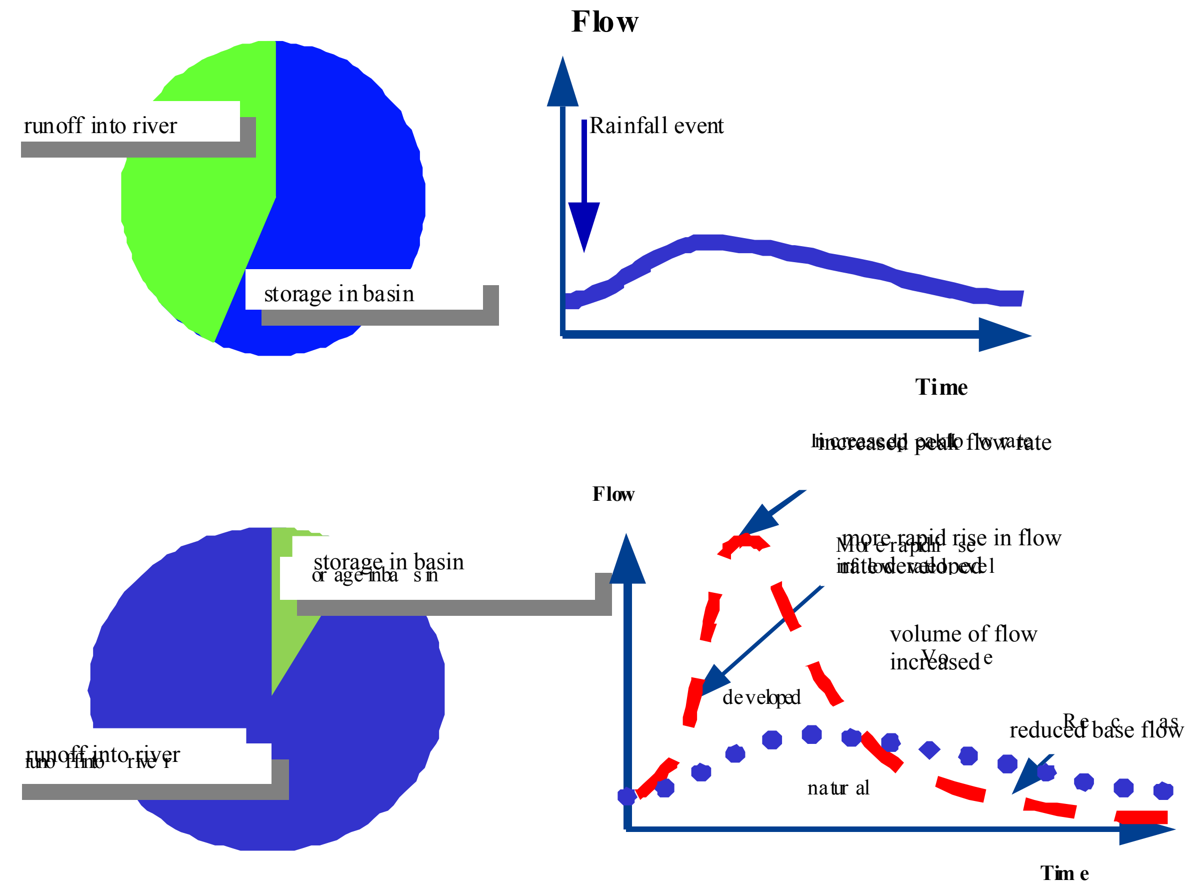


Figure 2.2: Rainfall runoff relationship showing two different surfaces (impervious and natural)

2.1 Impact of wastewater and stormwater

The impact of organic substances in wastewater is discussed in Section 1, while the impact of pathogens and toxic chemicals in wastewater on human health is discussed in detail in Appendix 2. The consequent loss of economic productivity due to illnesses, medial bills or inability to perform work at full capacity has been estimated to be in the order of billions of dollars per day.

Solids in both wastewater and stormwater form sediments and can eventually clog drains, streams and rivers. Grease particles form scum and are aesthetically undesirable.
The nutrients N and P cause eutrophication of water bodies, with lakes and slow moving waters affected to a greater degree than faster flowing waters. In the former the algae which are fertilised by the nutrients, settle as sediment when they decay. The sediment acts as a store of nutrients and regularly releases the nutrients to the water column, thus the cycle of bloom and decay of the algae is intensified. In the early stages of eutrophication aquatic life is made more abundant, because fish, for example, graze on the algae. With too high a concentration of algae, the decaying algae contribute to BOD and the water is deoxygenated. Thus wastewater, which has been treated to reduce BOD but still high in nutrients, can still have a significant impact on the receiving water. Some algae produce toxins which can be harmful to bird life and irritate skins coming into contact with the water. Eutrophic water adds to the cost of water treatment, when the water is used for drinking purposes.

Other pollutants in wastewater and stormwater are heavy metals and possible toxic and household hazardous substances. Heavy metals include copper, zinc, cadmium, nickel, chromium and lead. The content and concentration are dependent on the pipe materials employed to convey drinking water, household cleaning agents used, and for stormwater the type of materials used for roofing and guttering. In high enough concentrations these heavy metals are toxic to bacteria, plants and animals, and to people. Toxic materials may also be disposed with household wastewater. These could be medicines, pesticides and herbicides which are no longer used, excess solvents, paints and other household chemicals. These substances can corrode sewer pipes and seriously affect operation of treatment plants. They will also limit the potential of water reuse, and therefore should not be disposed with household wastewater.

Spills of chemicals, particulates from motor vehicle exhaust and deposition of atmospheric pollutants can similarly contaminate stormwater. These pollutants will affect downstream receiving waters, and treatment systems if the stormwater is treated.

Wastewater and contaminated stormwater can contaminate groundwater. This is through infiltration of the wastewater or stormwater through the soil to unconfined groundwater aquifer. Soil can filter some pollutants (see 2.2 Natural purification processes), but soluble pollutants (e.g. nutrients and heavy metals) and very small particles (e.g. virus) travel with the water to the groundwater aquifer.

Heavy storm events can cause flooding. The effects of flooding can be severe. Water levels in drain, stream and rivers rise considerably and the flow of water can erode soils and embankments. Sediments which have been deposited in quiescent stretches of a stream can be resuspended and transported further downstream. In urban areas the water picks up litter and solid wastes in its path as well as other diffuse pollution sources, and spread these in the downstream flooded areas. Aquatic environments and water-fowl habitats can be destroyed, and these may take some time to recover. The amenity value of these, as well as recreational lakes, is therefore degraded. Engineered structures, such as culvert and bridges, can be choked with wastes and debris, causing more wide-spread flooded areas.

2.2 Natural purification processes

Before considering technologies for wastewater and stormwater management it is instructive for us to examine natural processes that cycle waste materials. In nature waste materials are produced by living organisms (plants, animals and people). These wastes include faecal materials, leaf litter, food wastes and dead biomass. Yet streams and rivers flowing through a pristine forest, or freshwater lakes in a forest, have generally an excellent water quality. Thus there are natural processes which purify the naturally produced wastes. These wastes are characterised by their organic nature (that is derived from living or once living organisms). They consist of carbon, nitrogen, phosphorus and other elements which constitute the building blocks of living organisms. These elements are continuously cycled in nature. Three of them (carbon, nitrogen and phosphorus cycles) and the water cycle are relevant to wastewater and stormwater management. Figure 2.3 shows the natural carbon cycle.

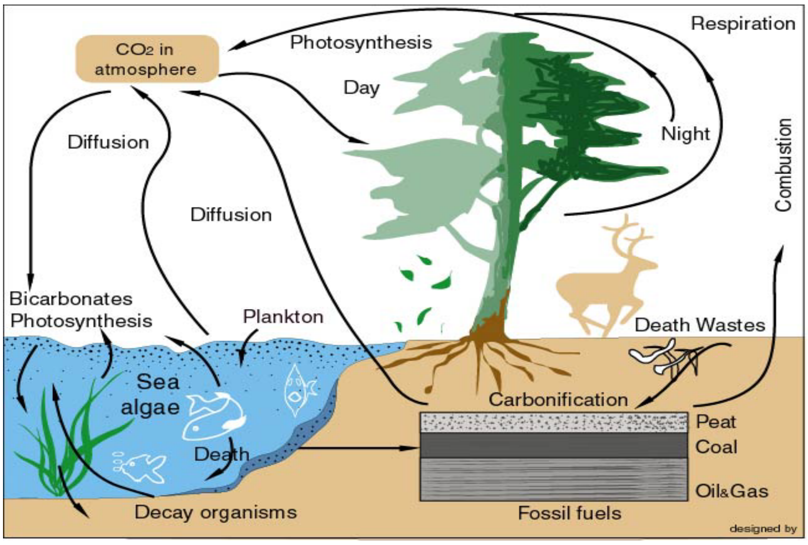


Figure 2.3: Carbon cycle

The following transformation processes occur in the carbon cycle. Plants photosynthesise glucose from carbon dioxide gas and water, and in turn more complex organic matter is synthesised. Plants are consumed by plant-eating animals, which in turn are consumed by meat-eating animals. Organic carbon compounds are digested by these animals and re-synthesised into other forms, which are useful for energy, cell growth and cell multiplication. Carbon dioxide is released into the atmosphere during the process of respiration. The respiration process releases energy for the organism through oxidising the organic carbon. Plants and animals produce waste materials and will eventually die. Leaf litter, animal wastes and dead organic matter are decomposed by bacteria and other decomposers releasing the carbon as carbon dioxide thus completing the carbon cycle. Oxygen is required in the process of respiration and oxidation of organic carbon, and this is the reason for the oxygen demand of organic wastes. Some organic matter from dead animals and plants is, however, stored in nature, particularly in sediments, and slowly turns into peat or more stable carbon-rich materials.

In the process of decomposition not only is carbon released as carbon dioxide, but other minerals are released. These minerals are involved in other cycles, such as the nitrogen cycle (Figure 2.4) and phosphorus cycle (Figure 2.5).

Ammonia is generally the form of nitrogen released from the decomposition of organic wastes. Provided that oxygen is available the ammonia is oxidised by a group of bacteria (termed nitrifiers) to nitrate. This process is another that exerts oxygen demand on the environment. Nitrate is the form of nitrogen that is normally taken up by plants for protein synthesis. Nitrate may on the other hand, under conditions devoid of oxygen (anaerobic conditions), be converted by a group of bacteria (termed denitrifiers) to nitrogen gas. Denitrification generally takes place in sediments, where anaerobic conditions and availability of organic carbon promote the process.

Nitrogen gas in the atmosphere is very large in quantity, but is inert. Relatively small quantities are converted into forms that can be utilised by plants. These are converted through the activity of nitrogen-fixing bacteria in the root-nodules of some plants, nitrogen-fixing blue-green algae or through lightning. Some is contributed by volcanic eruption. The amount of nitrogen cycled in a natural environment is therefore relatively small and is rapidly absorbed by plants.

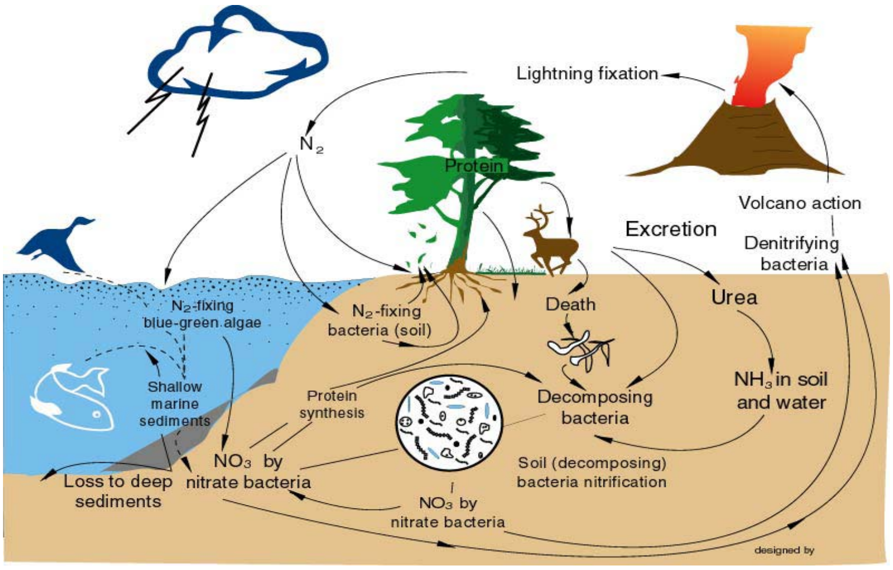


Figure 2.4: Nitrogen cycle

Phosphates are the products of decomposition of organic matter by decomposers and these are also the forms that are taken by plants. Phosphate rock, from which phosphate for fertiliser is mined, is an accumulation of phosphorus from the excretion of the guano birds and that is not utilised by plants at the deposition site.

From examination of the above natural cycles it is clear that very little organic wastes and nutrients are leached from natural ecosystems. In addition in a forest ecosystem the surface run-off has a low peak and extends over a longer period, thus solids are filtered from the water, and nutrients have a higher likelihood of being absorbed by plants. The soil in a forest ecosystem can provide additional purification processes. Soil bacteria will consume organic carbon and reduce BOD. Soil minerals (particularly clay minerals) can adsorb metals and phosphates. Plant roots take up nutrients released by bacterial decomposition from water percolating through the soil.

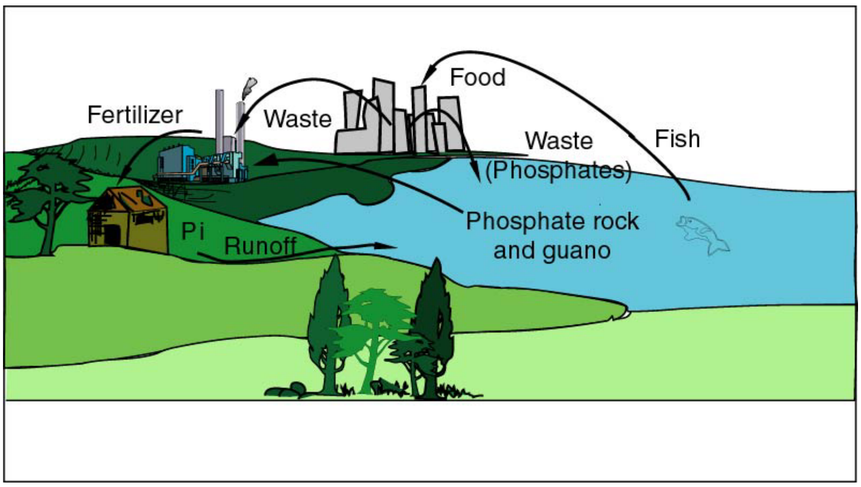


Figure 2.5: Phosphorus cycle

Pathogens, if any, generally die-off, because of unfavourable conditions outside their hosts for an extended period and competition with naturally occurring mirco-organisms. The water cycle therefore produces surface water and groundwater of very high quality (Figure 2.6).

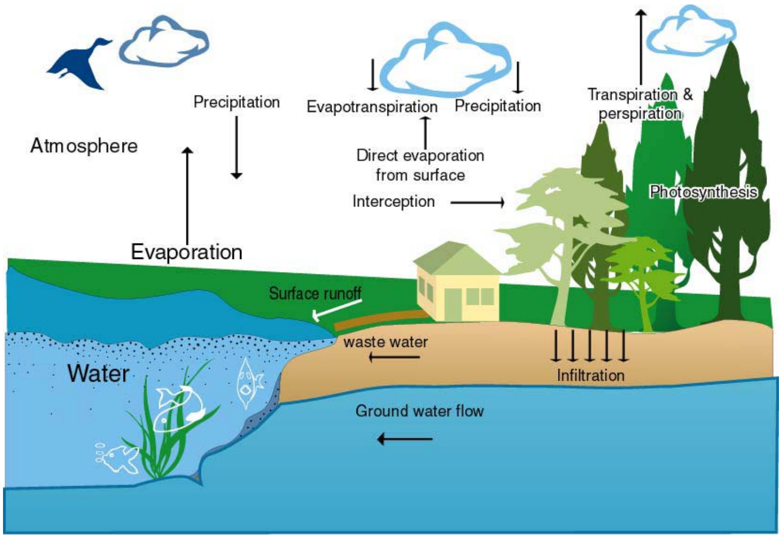


Figure 2.6: Water cycle

The natural cycles (also termed biogeochemical cycles) can provide an insight into the natural basis of wastewater and stormwater management. For disposal of wastewater and stormwater into a natural ecosystem, as long as the natural purification capacity of the ecosystem is not exceeded, we can rely on the existing natural processes to assimilate the wastes without degrading the quality of the environment. On the other hand once the natural capacity is exceeded, engineered systems are required. There is no reason, however, why the same physical, chemical and biological processes taking place in nature cannot be used as a basis for technology development and for waste management.

We note that in nature the cycling of the elements provide a pathway for reuse of the materials in the wastes. We should consider how we can use the same processes to recycle wastewater and stormwater. A limitation of natural purification processes is that they can only handle naturally occurring wastes. The latter can include human wastes, but not toxic chemicals that stop the natural processes. In addition a large human settlement removes a large area of natural ecosystem and generates a large amount of wastes, and the combination of the two rapidly and significantly impact on our natural environment. Clearing of vegetation reduces evapotranspiration, while roads and houses introduce impervious surfaces. Consequently rainfall run-off has a higher peak and is generated rapidly, promoting local flooding (Figure 2.2).

2.3 The role of micro-organisms

As can be seen in Section 2 (2.2) micro-organisms, such as bacteria, play an important role in the natural cycling of materials and particularly in the decomposition of organic wastes. The role of micro-organisms is elaborated further here because they are also important in the treatment of wastewater. What is waste for humans and higher vertebrates becomes a useful food substrate for the micro-organisms. In both natural and engineered treatment systems micro-organisms such as bacteria, fungi, protozoa, and crustaceans play an essential role in the conversion of organic waste to more stable less polluting substances. They form what is termed a 'food chain'. For example inorganic and organic substances in wastes are consumed by bacteria, fungi and algae. These are in turn consumed by protozoa and nematodes (some fungi however trap nematodes) and the latter by rotifers.

In a natural water body, e.g. river or lake, the number and type of micro-organisms depends on the degree of pollution. The general effect of pollution appears to be a reduction in species numbers. For example in a badly polluted lake, there are fewer species but in larger numbers, while in a healthy lake there can be many species present but in lower numbers.

Micro-organisms are always present in the environment and given the right conditions of food availability, temperature and other environmental factors, they grow and multiply. Figure 2.7 shows a generalised pattern of growth of micro-organisms.

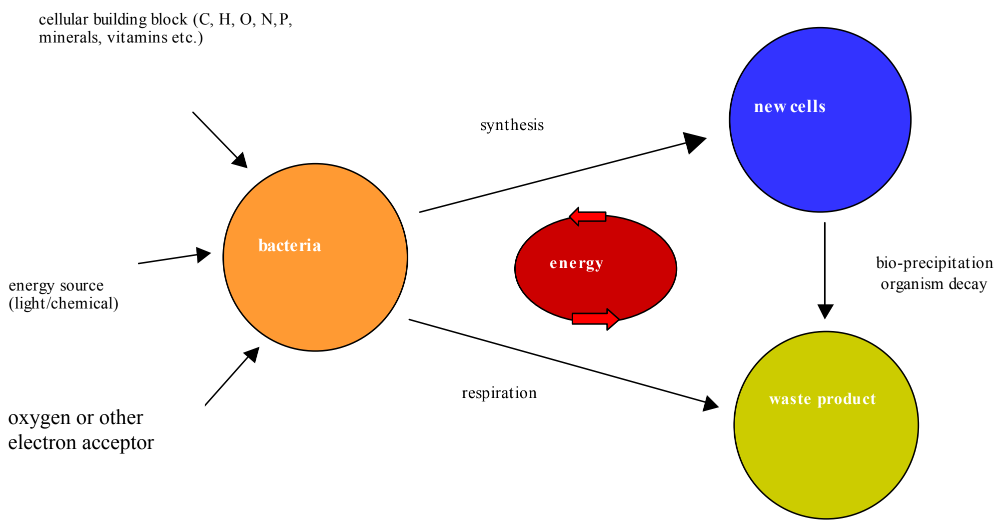


Figure 2.7: Generalised representation of growth of micro-organisms

Micro-organisms require cellular building blocks, such as (carbon) C, (hydrogen) H, (oxygen) O, (nitrogen) N, (phosphorus) P, and minerals for growth. These can be obtained through consuming organic substances containing these elements, or from inorganic materials, such as carbon dioxide, water, nitrate and phosphate. Micro-organisms also require energy. They obtain this through respiration. In this process organic carbon is oxidised to release its energy. Oxygen or other hydrogen acceptors is needed for the respiration process. Algae and photosynthetic bacteria can also utilise energy from sunlight, while certain types of bacteria can utilise energy from chemical reactions not involving respiration. The building blocks and energy are used to synthesise more cells for growth and also for reproduction.

In the treatment of wastewater three types of overall processes are distinguished to represent the conversion of organic wastes by micro-organisms. The classification is based on whether the environment where the process takes place is aerobic, anaerobic or photosynthetic. Under aerobic conditions (in the presence of oxygen), micro-organisms utilise oxygen to oxidise organic substances to obtain energy for maintenance, mobility and the synthesis of cellular material. Under anaerobic conditions (in the absence of oxygen) the micro-organisms utilise nitrates, sulphates and other hydrogen acceptors to obtain energy for the synthesis of cellular material from organic substances. Photosynthetic organisms use carbon dioxide as a carbon source, inorganic nutrients as sources of phosphate and nitrogen and utilise light energy to drive the conversion process.

Micro-organisms also produce waste products, some of which are desirable and some undesirable. Gases such as carbon dioxide and nitrogen are desirable, since they can be easily separated and do not produce pollution. Gases such as hydrogen sulphide and mercaptans, although easily separated require treatment for odour. Micro-organisms' cellular materials are organic in nature and can also cause pollution. It would be desirable if the cellular materials have undergone self oxidation (endogeneous respiration utilising own body cells) to produce non-biodegradable materials that are relatively stable. Self-oxidation is achieved when there is no substrate/food available.

The microbiological conversion reactions of organic waste into cellular material can be empirically represented as shown below.

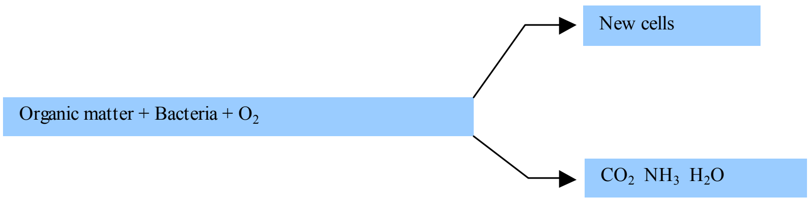
(i) Conversion under *aerobic conditions (see diagram below)*:

Under aerobic conditions ammonia is further oxidised to nitrate. Phosphorus and sulphur contained in the organic substances are oxidised to phosphate and sulphate. These can be further utilised by the micro-organisms for synthesis.

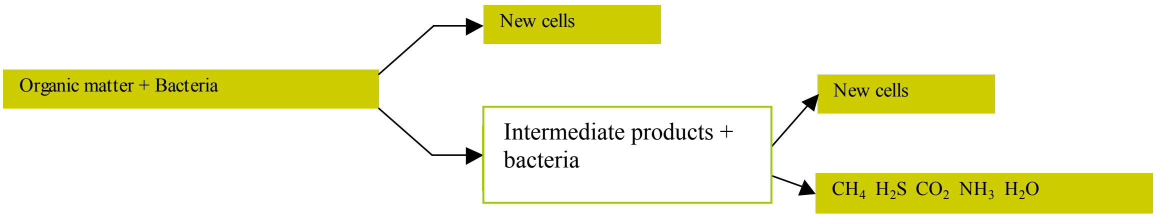
(ii) Conversion under *anaerobic conditions (see diagram below)*:

Methane (CH_4) is a useful gaseous by-product of anaerobic conversion, because it can be combusted to produce heat/energy. On the other hand if it is released to the atmosphere without being combusted, it contributes to the greenhouse gas effect.

Aerobic Oxidation



Anaerobic Oxidation



(iii) Conversion under *photosynthetic conditions*:

$$aCO_2 + rH_2O + tNH_3 \xrightarrow{\text{sunlight}} C_w H_x O_y N_z + bO_2$$

As shown by the conversion reactions (the utilisation of organic wastes for food by micro-organisms) the product is mainly the cellular material of the micro-organisms i.e. more organisms are produced. The growth yield is the weight of micro-organisms produced per unit weight of organic substances consumed by the micro-organisms. The growth yield depends on the type of substrate and environmental conditions. The smaller the value of the growth yield the better it is for waste treatment, because less sludge is produced which requires disposal. Its value is usually between 0.2 and 0.5 for aerobic conversion, while the corresponding value for anaerobic conversion is smaller.

2.4 Sustainable versus unsustainable wastewater and stormwater management

The natural purification processes and biogeochemical cycles described in section 2 (2.2) provide a basis for determining what is environmentally sustainable management practices for wastewater and stormwater. Discharge of wastewater and stormwater into an environment exceeding the natural purification capacity of that environment will result in the accumulation of organic materials (carbon), nitrogen, phosphorus or other pollutants that cannot be absorbed by the ecosystem constituting the receiving environment. Accumulation of organic materials will result in a high oxygen demand that cannot be met by oxygen transfer from the atmosphere. Undesirable anaerobic conditions are a consequence (See section 1 (1) on discharge of wastewater with a high BOD to a river). Figure 2.8 illustrates an unsustainable practice where the natural purification capacity of a river into which wastewater is discharged is exceeded, and where in addition the local biogeochemical cycles are not closed.

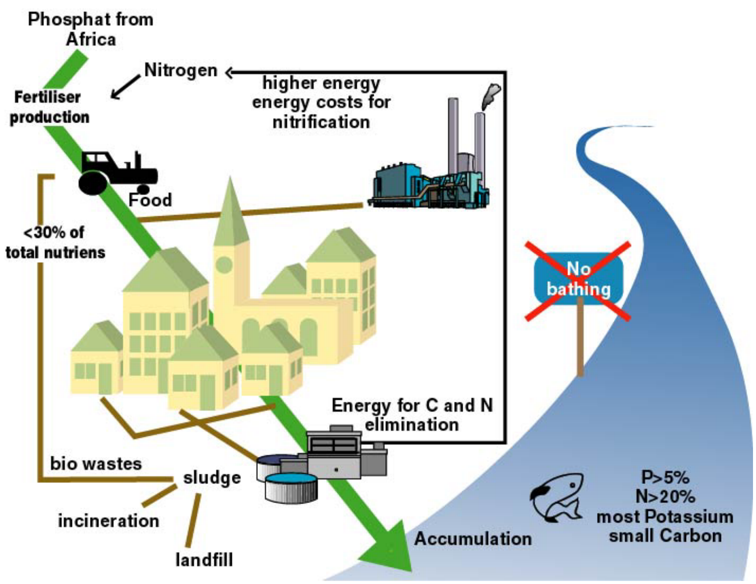


Figure 2.8: Unsustainable wastewater management practice from not closing the local biogeochemical cycles resulting in the natural purification capacity of the receiving environment to be exceeded (Lange and Otterpohl, 1997).

Nitrogen and phosphorus in wastewater are discharged to a river resulting in their accumulation in the river. Eutrophication of the river is an outcome. The nitrogen and phosporus in the wastewater come from food consumed by people. To grow this food fertilisers containing nitrogen and phosphorus are required. These are manufactured chemically from atmospheric nitrogen and from phosphate rock. The flow of materials (N & P) is one way from the atmosphere for N and from the phosphate rock mine for P into the river. There is depletion of a resource (mined phosphate rock) and accumulation and pollution in the river. This practice is unlikely to be sustainable in the long term, because phosphate rock deposits will be exhausted and pollution of the river by N and P needs further treatment of the wastewater.

One way of managing the wastewater sustainably is by closing the material cycles locally (Figure 2.9).

Nutrients in the wastewater are reused to grow food. In this way there is not the need to to use as much chemical fertilisers and at the same time there much less discharge of nutrients to the river. The problem of resource depletion and pollution of the river is overcome by closing the material cycles. Figure 2.9 also emphasises the need to treat industrial wastewaters containing toxic substances separately, and not to mix industrial wastewaters with domestic wastewater. In addition stormwater should be separately collected and treated and infiltrated locally.

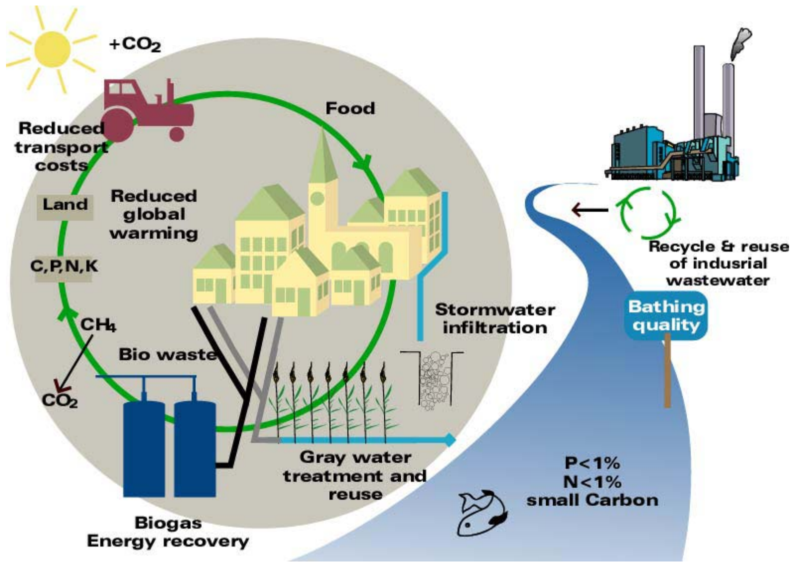


Figure 2.9: Sustainable wastewater management practice by closing the local biogeochemical cycles (Lange and Otterpohl, 1997).

3. Wastewater and stormwater collection (Topic b)

Collection of wastewater is by use of a sewerage system. Depending on whether blackwater is generated separately from greywater, or mixed with it, we need to collect greywater or the mixture of blackwater and greywater (sewage). Gravity is used wherever possible to convey the wastewater. It is not surprising therefore that natural stormwater drainage has been used, because this is how rainwater run-off is conveyed in nature by gravity. The stages of development of the use of a natural drainage system for conveying both wastewater and stormwaster have been described in Section 1, outlining its evolution from lining and covering of the drains, to the trend of separately collecting wastewater and returning the stormwater drainage to its more natural state.

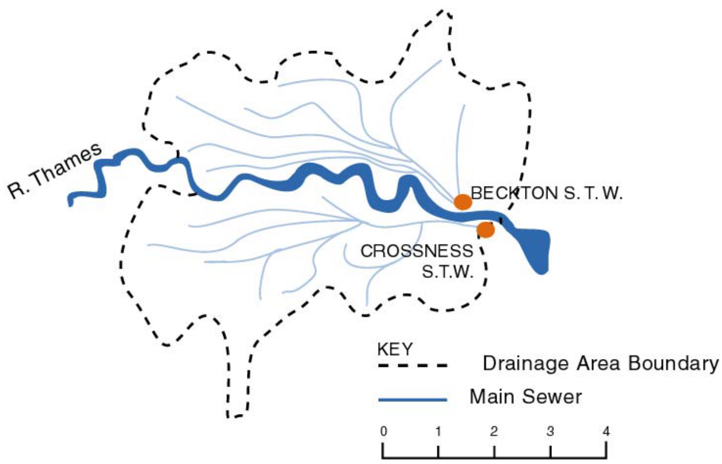


Figure 2.10. Plan of London's sewerage, showing the main sewers and drainage areas of Beckton and Crossness wastewater treatment plants.

The principle of using gravity as the driving force for conveying wastewater in a sewerage system should be applied wherever possible, because this will minimise the cost of pumping. Natural stormwater drainage occurs in what is usually termed a catchment basin. In a catchment basin rainwater run-off flows to a common point of discharge, and in so doing form streams and rivers. Crossing a catchment boundary may mean that the water has to be unnecessarily pumped, requiring an energy source. A wastewater sewerage system should therefore be within a stormwater catchment basin. Figure 2.10 shows an example of wastewater collection in a catchment basin.

Sewerage systems can be classified into combined sewerage and separate sewerage. Combined sewerage carries both stormwater and wastewater, while separate sewerage carries stormwater or wastewater separately. Recent trends have been for the development of separate sewerage systems. The main reason for this is that stormwater is generally less polluted than wastewater, and that treatment of combined wastewater and stormwater is difficult during heavy rainfalls, resulting in untreated overflows (commonly termed combined sewer overflow, CSO). In practice there is usually ingress of stormwater into wastewater sewerage pipes, because of unsealed pipe joints, and unintentional or illegal connections of rainwater run-off. Conversely there may be unintentional or illegal wastewater connections to stormwater sewerage.

Wastewater sewerage systems can be classified into three major types: 1. Conventional sewerage, 2. Simplified sewerage and 3. Settled sewerage

3.1 Conventional sewerage

Conventional sewerage is also termed deep sewerage. This term results from the fact that in actual practice the sewerage pipes are laid deep beneath the ground. There are a number of reasons for the relatively great depth of the pipes. A minimum velocity is needed to ensure that self-cleansing conditions occur at least once daily (usually 0.75 m/s). Combined with a minimum specified diameter (usually 150 mm internal diameter), the outcome is the requirement of steep gradients for the pipes. Added to this is the specification for a minimum depth of buried pipes to avoid interference with road traffic and other services (minimum of 0.9 to 1.2 m). Main sewerage trunks are therefore generally quite deep if gravity is relied upon as the driving force for flow. Figure 2.11 shows a typical layout for a deep sewerage system.

Pumping is generally required at various stages of the sewer pipe network, especially if the landscape is fairly flat. The larger the population served by the sewerage system, and the longer the planning horizon is to cope with future population increases, the larger the diameter of the final pipes becomes. The costs of the pipes, inspection manholes, pumps and pumping stations and their construction/installation are therefore high. The costs of operation and maintenance are correspondingly high.

The design procedure for conventional sewerage is well developed from its early beginnings in the provision of sewerage in the city of London and other European cities. It is now acknowledged that the design procedure for the conventional sewerage is based on very conservative assumptions.

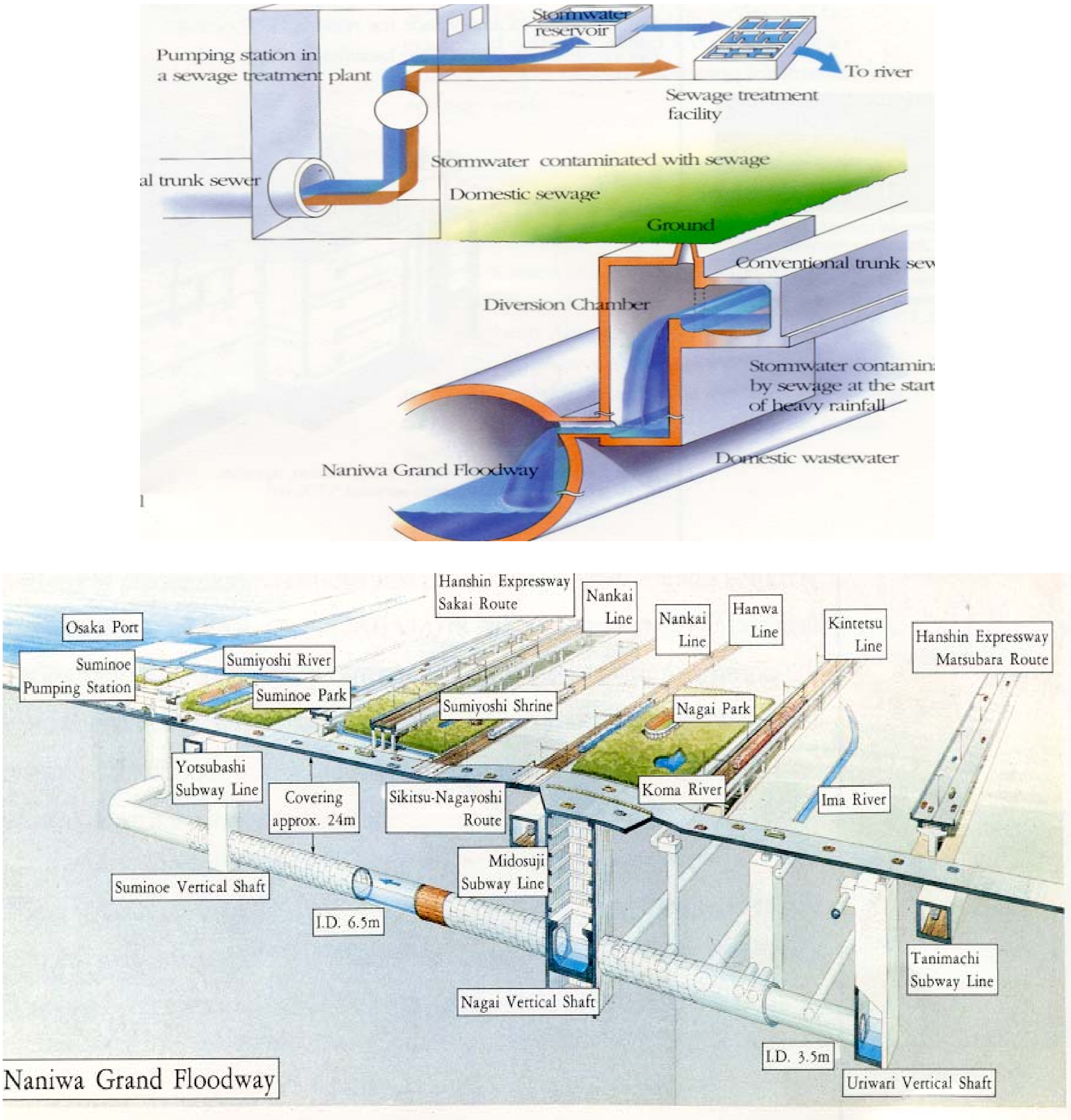


Figure 2.11: Sewerage system for the city of Osaka

3.2 Simplified sewerage

Simplified sewerage is also known as shallow sewerage. Again the term reflects the nature of the shallower placement of the pipes in contrast to the conventional or deep sewerage. The purpose of simplified sewerage is to reduce the cost of construction and the corresponding cost of operation and maintenance. Simplified sewerage is designed based on hydraulic theory in the same manner as for conventional sewerage. Its design assumptions are, however, less conservative. Smaller diameter pipes are used when water use per person is known to be less. Minimum depth of cover of pipes can be as low as 0.2 m when there is only light traffic. Manholes can be replaced by inspection cleanouts because of the shallow pipes. Design planning horizon can be 20 instead of 30 years, because population projection may be uncertain. In a variation of the simplified sewerage the pipe layout passes through property lots (condominial) rather than on both sides of a street (conventional). Figure 2.12 shows a comparison between sewerage layout in conventional sewerage and in condominial sewerage, while Table 2.3 shows a comparison of length of pipes required. Cost of construction can be 30 to 50 % less than conventional sewerage depending on local conditions.

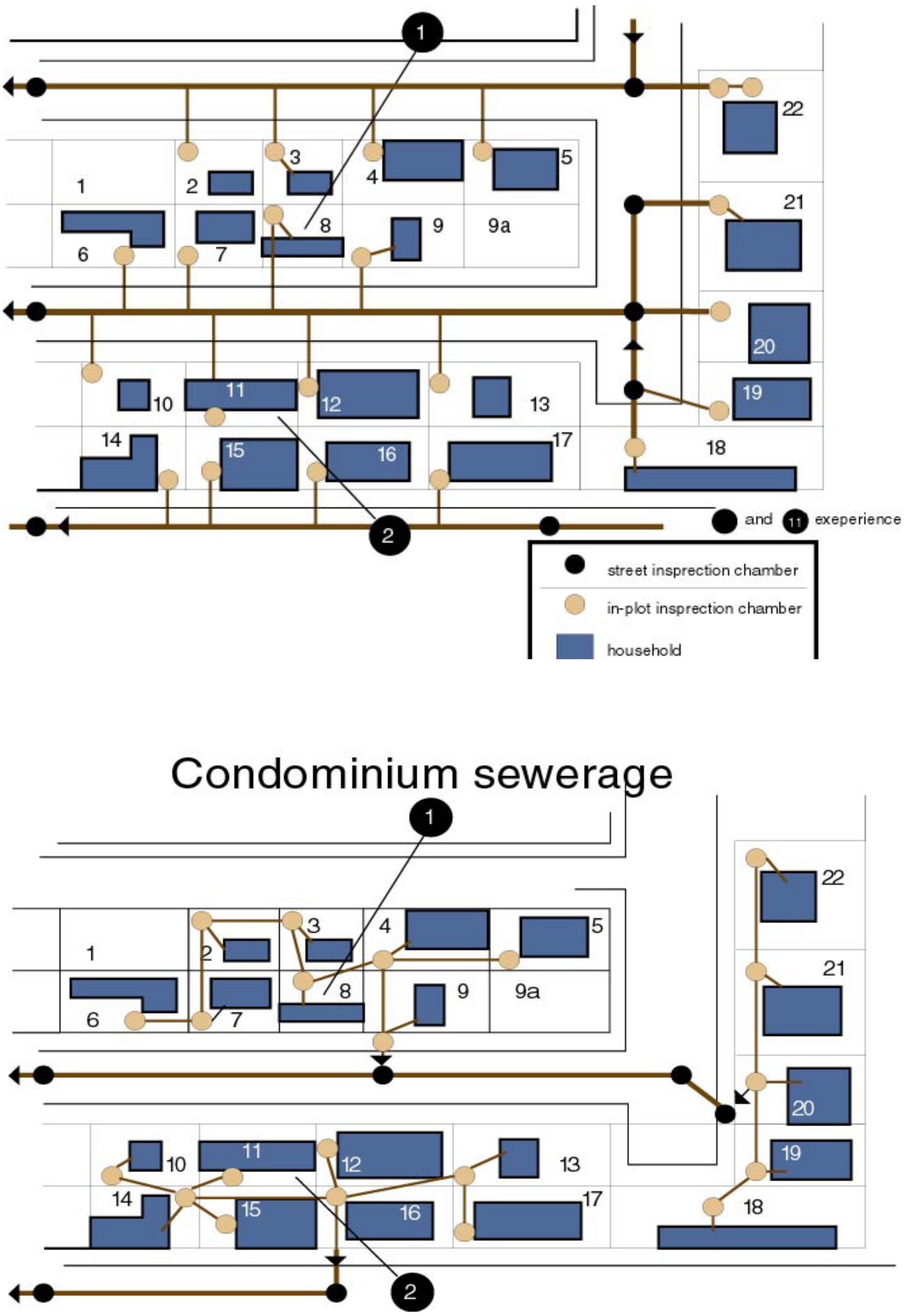


Figure 2.12: Pipe layout for (a) conventional and (b) condominium sewerage

Shallow sewerage is also conducive to local community participation. This is because of sewer pipes having to cross property boundaries and hence the need for the community to agree to this arrangement. This arrangement needs to be in place not only during construction, but also for maintenance (e.g. unblocking of sewer pipes). The shallow pipe, and hence the shallow trenches, also allow members of the community to participate by for example providing labour for digging the trenches. This is in contrast to conventional sewerage where specialised machinery is required for the deep trenches. Figure 2.13 contrasts the two approaches.

Table 2.3. Comparison of length of pipes required for conventional and condominium sewerage

LAYOUT	ON SITE PIPES/ HOUSEHOLD (m)	HOUSING CONNECTIONS/ HOUSEHOLD	SEWERAGE HOUSEHOLD (m)
1. Conventional	0.9	9.9	12.8
2. Condominium	2.5	10.9	6.0

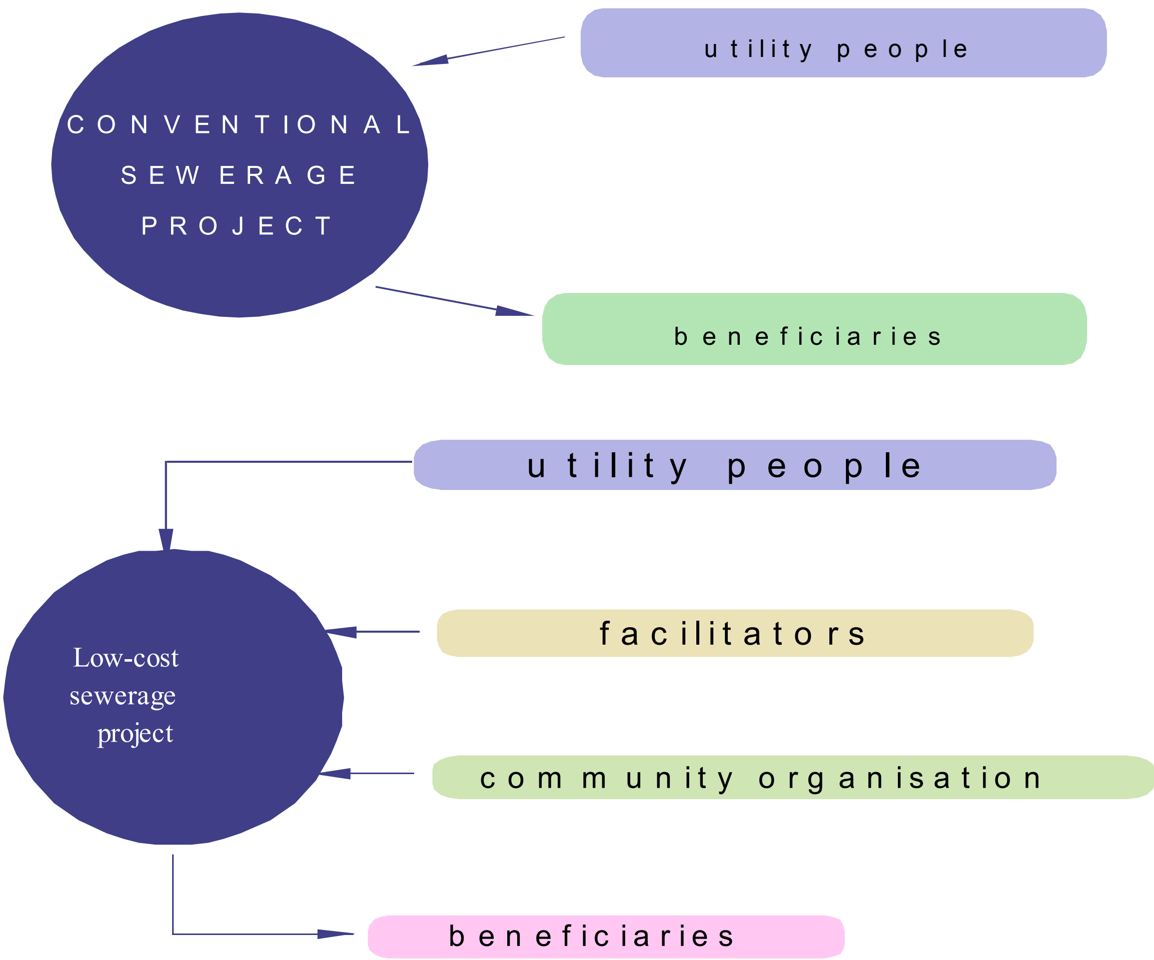


Figure 2.13: Contrast in community participation between conventional and condominial sewerage

There has been considerable experience with simplified sewerage (Regional Overview of Central & South America) and manuals have been produced to assist engineers with its design. Developed initially in Brazil it is beginning to be used in many parts of the world.

3.3 Settled sewerage

Settled sewerage refers to sewerage for conveying wastewater that has been settled, for example in a septic tank. The origin of settled sewerage is to convey overflow from septic tanks where the soil cannot cope or absorb the overflow. This usually occurs when the groundwater table is high, or where the soil permeability is low, or where there are rock outcrops. It can also be used when effluent from septic tanks pollutes groundwater and it is necessary to convey the effluent off-site and treat it. Because there are no solids that can potentially sediment in the sewerage pipes, there is no requirement for the self-cleansing velocity. Smaller pipes and lower gradients can be used. The cost of settled sewerage is between a third and a half of conventional sewerage. Originally developed in South Australia to overcome problems with failing septic tanks, it has been used quite widely worldwide to upgrade septic tank systems.

Where there is no existing septic tank, an interceptor box or tank can be used. It functions like a septic tank and designed in the same way (Figure 2.14). To reduce cost the wastewater from a group of houses can be connected to one interceptor tank. Just like in a septic tank, accumulation of sludge has to be removed regularly from an interceptor tank.

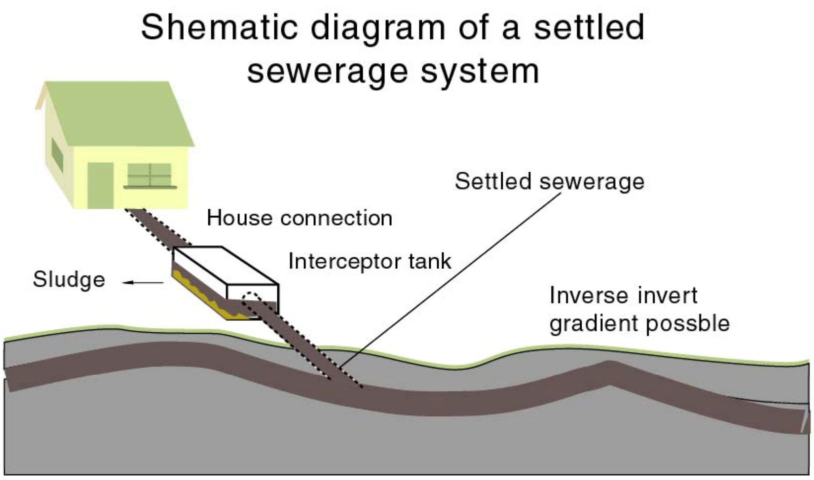


Figure 2.14: Interceptor tank in settled sewerage

3.4 Stormwater collection

As mentioned in the introduction to this section (2 (3)), stormwater naturally flows through the landscape's natural drains. Piped stormwater collection was a development in European cities to overcome odour and improve aesthetic appearance of wastewater disposed with stormwater. The covering of ditches used for combined sewerage was an intermediate step in using natural drainage to construct sewerage for combined wastewater and stormwater (Section 1). Piped sewerage also allows more land area for road and footpath. With separate collection of wastewater there is an opportunity to return some stormwater flow path to its more natural state to improve urban amenity value.

4. Wastewater and stormwater treatment (Topic c)

Treatment of wastewater and stormwater means the removal of pollutants from the water. The first principle to bear in mind therefore is to prevent pollutants from entering the water in the first place. Reference to preventing litter entering stormwater drains has been made above. In the case of stormwater we need to ensure that surfaces through which stormwater run-off passes over should as far as possible be free from solids and other wastes. Thus collection of solid wastes is an important part of stormwater treatment or its prevention. Separately collecting of wastewater and stormwater also belongs to this principle. Treatment of industrial wastewaters before discharge to the sewer is highly important in this regard.

In the case of wastewater, separating blackwater and greywater can mean less energy is required in treatment. This is because blackwater contains most of the solids, which during treatment have to be removed from the mixture. Further separating urine and faecal materials may also mean that the urine can be reused without much treatment and the faecal materials can be more simply treated. The use of water to convey toilet wastes may be questioned based on this principle, because treatment means separating these wastes from the water.

Besides preventing pollutants entering the water, water conservation means that less volume of water has to be treated. Since the size of treatment systems is primarily governed by the volume of water to be treated rather than the amount of pollutants in the water, less volume means smaller treatment plants and corresponding capital cost. Use of less water to flush toilets belongs to this principle.

A range of wastewater treatment technology options is presented below. Treatment of wastes on-site is considered first (4.1), followed by off-site treatment of the wastewater (4.2). Treatment principles are related to natural purification processes described in Section 2 (2.2). Each technology requires maintenance and proper operation. The demand of each technology for maintenance varies and this is also discussed, as well as public health and environmental impacts of the technology. Treatment options for stormwater are presented in section 4.3.

4.1 On-site wastewater treatment systems

On-site treatment relies on decomposition of the organic wastes in human excreta by bacteria (Section 2 (2.3)). This can take place in a simple pit in the ground or in specially designed tanks to promote the bacterial decomposition of the wastes. Unless re-use of the wastewater is specifically intended (see Section 2 (6) on Wastewater reuse), the overflow from the pit or tank is allowed to soak into the ground. Further bacteriological decomposition and soil filtration, adsorption and purification processes take place in the soil. Potential of groundwater pollution, however, exists with on-site treatment and disposal systems, because not all pollutants (e.g nitrate) are removed by these processes.

Pit latrine, pour flush latrine, composting toilet, septic tank and two improved on-site treatment units are described below because they represent major types of on-site treatment systems. Variations of these exist and some are described in greater detail in the Regional Overviews for regions where these systems are used. The treatment principles are, however, covered under these major types.

4.1.1 Pit latrine

A pit latrine collects excreta in a pit dug in the ground beneath the toilet structure. If the soil is loose the pit needs to be lined with, for example, loose bricks to prevent the wall from collapsing. During storage in the pit decomposition of the organic substances takes place under anaerobic conditions. As described in Section 2 (2.3) the anaerobic decomposition releases gases (carbon dioxide and methane) and reduces the volume of sludge.

Seepage of water into the surrounding soil takes place through the sides and bottom of the pit. During seepage further decomposition of organic matter by soil bacteria takes place reducing the BOD of the water. There will also be die-off of bacteria and viruses during storage and as the water percolates through the soil. Nutrients are generally not removed by bacteria under these conditions, so pollution of groundwater will occur.

Control of odour and insects are important with a pit latrine. This is achieved by having a vented pit (Figure 2.15). The vent acts to draw odour and insects into the pit and up the vent. Gases (methane and carbon dioxide) produced by the decomposition of the excreta also leave through the vent. Natural convection can be relied upon by ensuring that the vent protrudes well above the roof of the housing. Facing the vent towards the sun (southward in the Northern hemisphere and northward in the Southern hemisphere) and painting the vent black to maximise absorption of heat from the sun will help venting by heat convection. The heated air in the vent rises and draws air from the toilet. Ventilated improved pit (VIP) toilets are widely used in Africa (see Regional Overview for Africa).

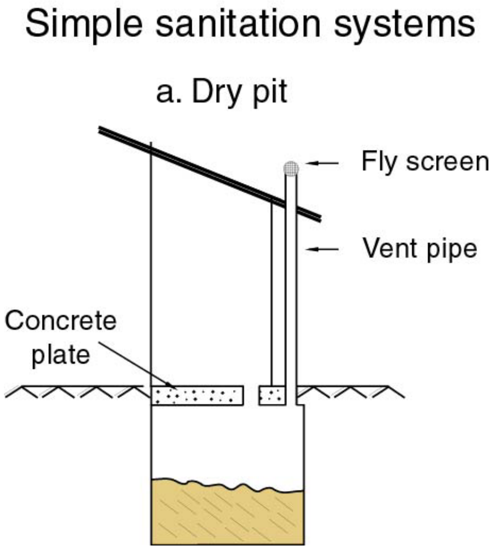


Figure 2.15: Ventilated Pit latrine

Pit latrines pose problems when groundwater is shallow and the pit is in groundwater or close to it. There is no soil barrier to protect the water quality of the groundwater, and mosquitoes may breed inside the pit. A pit is also difficult to dig when the ground is rocky. Pit latrines should not be used in these cases.

The pit will eventually fill with faecal sludge and needs to be emptied. The period between emptying depends on the size of the pit and its usage. It is desirable to design the pit to store at least one year of sludge production. Emptying requires mechanical suction of the sludge. The sludge requires treatment prior to re-use or disposal (see Section 2 (5)). Two adjoining pits can be used alternately. Further decomposition of sludge in a full pit takes place while the adjacent pit is in use. Its content after further decomposition can be manually removed.

An alternative way of dealing with a full pit is to dig another pit and relocate the sanitary platform and toilet housing to the new pit. The full old pit can then be covered with soil, preferably of greater than 15 cm depth to prevent disease vectors (rodents and insects) from burrowing into it.

4.1.2 Composting toilet

Rather than decomposition of the faecal sludge under anaerobic conditions (no oxygen) in the pit of a pit latrine, decomposition under aerobic conditions (with oxygen) can be promoted in an above ground (elevated) latrine (Figure 2.16). Air can be introduced through an opening to pass through the sludge and exit through the vent, while excess liquid is allowed to drain for collection or evaporation. With two adjoining composting chambers or vaults used alternately, the process of composting in an already full chamber can be allowed to proceed until the chamber is to be used again, and produce mature compost for direct re-use in the garden. Other household organic wastes (e.g. food wastes) can be added to the faecal sludge, and materials such as newspaper or sawdust can be added to balance the carbon to nitrogen ratio for optimal composting. Because mature compost takes several months to produce under ambient temperatures, it is desirable for the chambers to be sized to hold at least 6 months of wastes. Worms can also be added to assist with vermi-composting. Further details on handling and composting of sludge can be found in section 2 (5).

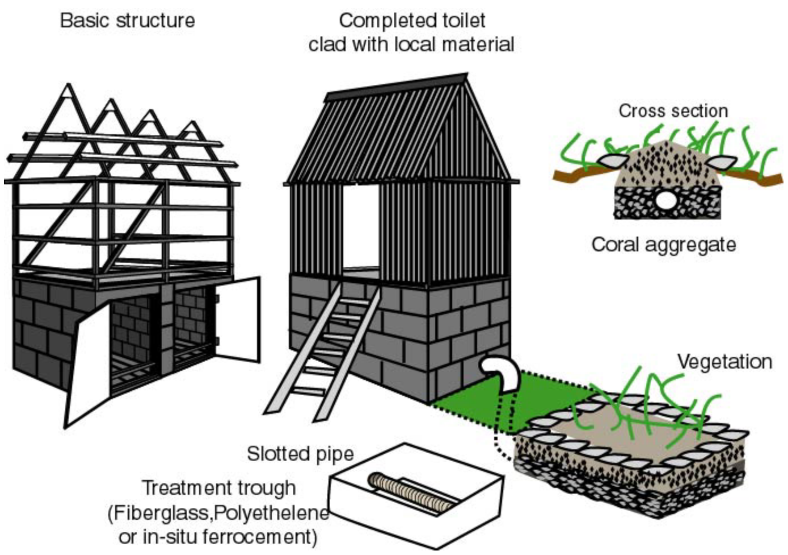


Figure 2.16: Composting toilet

4.1.3 Pour flush toilet

A pour flush toilet (Figure 2.17) has a water seal. The problems associated with odour and insects are avoided by having the water seal.

Excreta deposited in the latrine pan is flushed by pouring 2 to 3 L of water into it. The mixture is directed into a pit in the same way as for a pit latrine. The processes of biodegradation of the organic wastes in the pit are exactly the same. More water percolates through the soil surrounding the pit, and the potential for groundwater pollution is higher. A pour flush toilet with a pit is therefore not suitable when groundwater table is close to the surface.

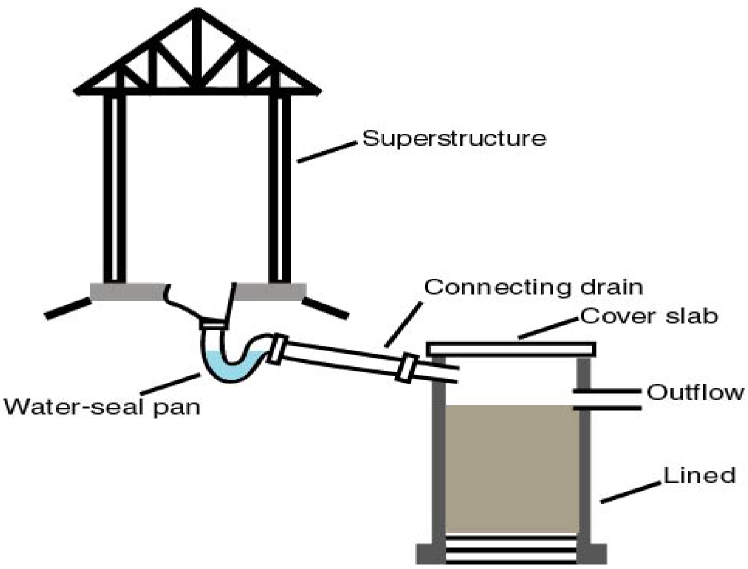


Figure 2.17: Pour flush latrine pan.

Sludge has to be regularly emptied from the pit. The use of two adjoining pits alternately enables the sludge in a full pit to undergo further decomposition while the other pit is being used, and enables manual sludge emptying after further sludge decomposition.

With the use of the pit latrine, composting toilet and pour flush latrine, greywater (sullage) has to be separately treated. Greywater can be reused directly or after treatment (see Section on Wastewater Reuse 2 (6)). Disposal of greywater on-site is by use of a leach pit or trench (See below under Septic tank). Limitations of disposal of greywater by leach pit or trench are similar to those applicable to septic tank.

4.1.4 Septic tank

A septic tank is a water tight tank, usually located just below ground, and receives both blackwater and greywater (Figure 2.18). It can be used with pour flush toilets or cistern flush toilets. It functions as a storage tank for settled solids and floating materials (e.g. oils and grease). The storage time of the wastewater in the tank is usually between 2 and 4 days. About 50 % removal of BOD and Suspended Solids (SS) is usually achieved in a properly operated septic tank due to the settling of the solids during wastewater storage.

A septic tank can be constructed of bricks and mortar and rendered, or of concrete. Its shape can be rectangular or cylindrical. A septic tank can be partitioned into two chambers to reduce flow short circuiting and improve solids removal.

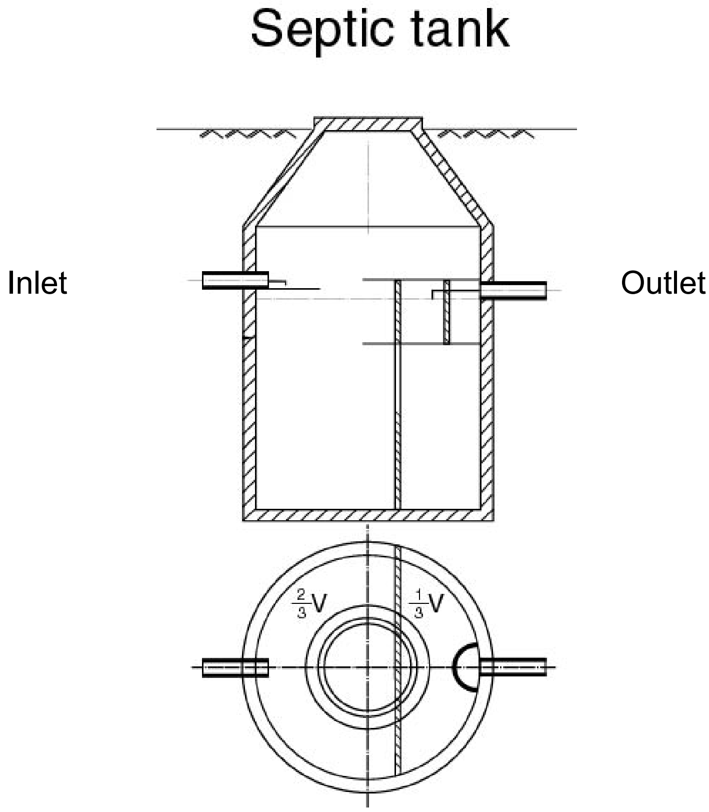


Figure 2.18: Septic tank

The overflow from a septic tank is directed to a leach pit or trench. A leach pit (Figure 2.19) is similar to the pit of a pit latrine or pour flush latrine. The pit must be sized to allow percolation of the volume of wastewater generated. A pit works well in soils with high permeability. In soils with lower permeability a trench can provide the larger surface area of percolation (Figure 2.20). The trench is usually filled with gravel and a distribution pipe for the wastewater is placed in this gravel layer. Soil is then placed above this gravel layer to the ground surface.

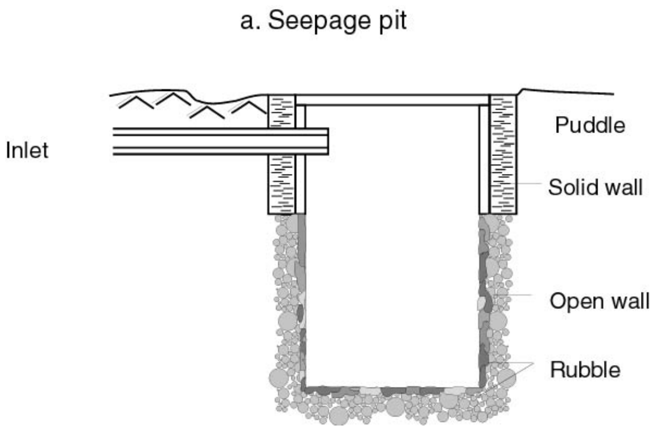


Figure 2.19: Leach pit (Seepage pit)

A leach pit or trench does not work when the soil permeability is too low (e.g. clayey soil or hard rock). In regions where annual evaporation is high, trees and shrubs can be used to help pump the water into the atmosphere by evapotranspiration. An evapotranspiration bed can be designed similar to a leach trench, but a suite of suitable local vegetation species tolerant of high nutrients and water are planted above and surrounding the trench (Figure 2.21). The trench should be sized to store water during the rainy season or low evaporation periods.

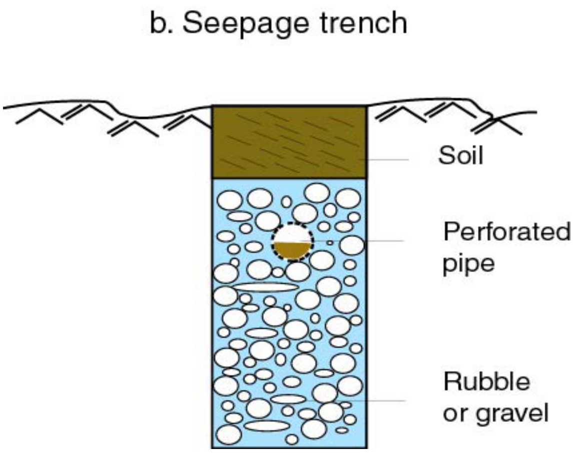


Figure 2.20: Leach trench for disposal of septic tank effluent

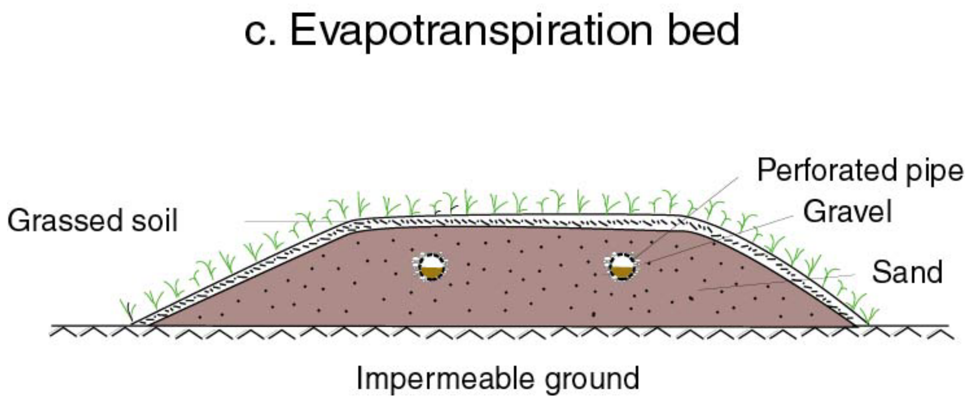


Figure 2.21: Evapotranspiration bed

A leach pit or drain does not work either when the groundwater table is close to ground surface. In this case off-site disposal is necessary using a settled sewerage system (Section 2 (3)). If the groundwater table is not too close, an inverted leach drain as described under Improved On-site Units below (4.1.5) can be used.

The organic solids in a septic tank undergo anaerobic bacterial decomposition just as in the pit of a pit latrine. The sludge needs emptying, and the period between emptying is usually designed to be between 3 to 5 years. The sludge has to be further treated before reuse or disposal (Section 2 (5)).

The septic tank overflow undergoes further bacterial decomposition as it percolates through a leach pit or trench. The decomposition is undertaken by soil bacteria, usually under aerobic conditions. The BOD of the wastewater can reach a low figure (<20 mg/L) if the distance between the bottom of the pit or trench to the groundwater table is greater than 2 m. Nutrients are not significantly removed by the bacteria and usually pollute the groundwater. Pathogenic bacteria are removed by die-off or filtration by the soil, but viruses may travel further in the soil or groundwater.

Percolation of septic tank overflow is much slower compared to rainwater percolation. This is because a layer of bacterial slime grows on the surfaces of the soil particles, restricting flow. Two leach pits or trenches used alternately, say every 6 months, are better than a single leach pit or trench of the same total area for percolation, because as one is used the other will recover its percolation rate.

4.1.5 Improved on-site treatment units

Improved on-site treatment units refer to treatment units which improve the performance of one of the above on-site systems, for reducing BOD, SS and/or nutrients. Two designs are described to illustrate the main principles used. A principal aim of the improvements is to prevent groundwater pollution or enable water reuse of the treated wastewater on-site. Many designs are available using similar principles. A number of these are described in detail in the Regional Overviews, where these units are used.

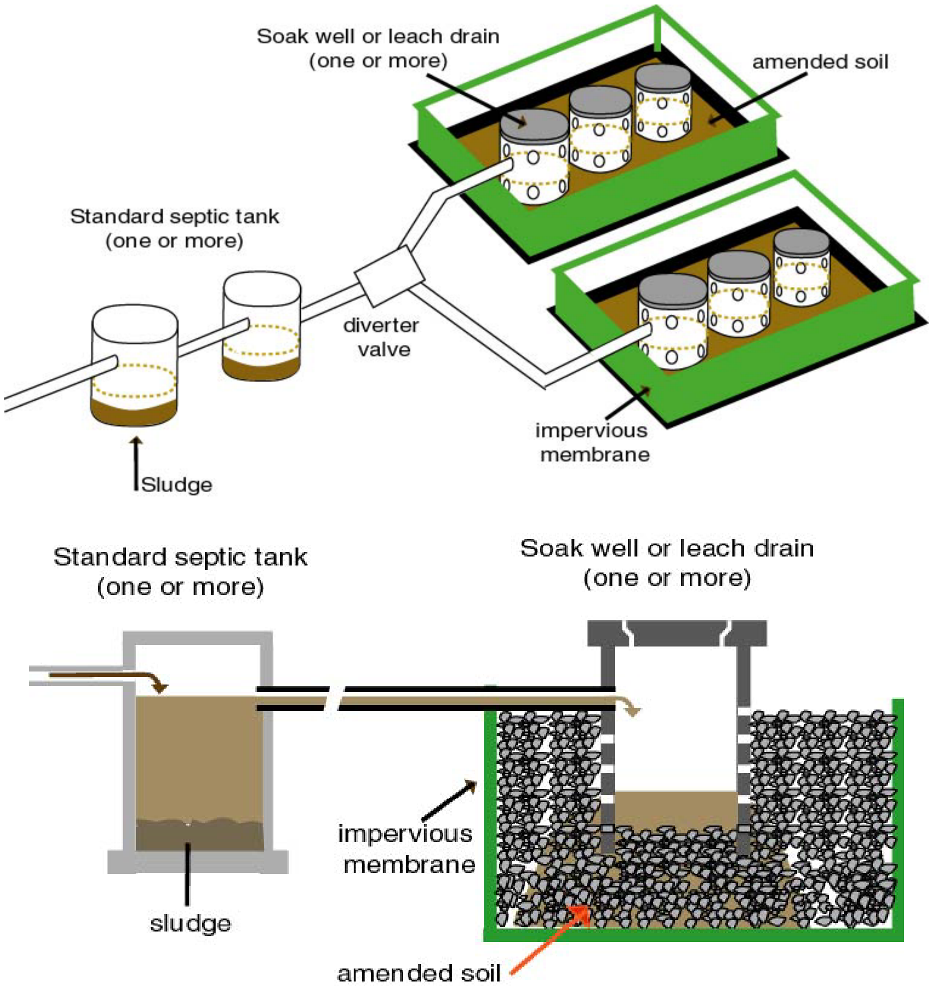


Figure 2.22: Inverted trench (Ecomax)

(a) Inverted trench

In the system illustrated in Figure 2.22 the trench of the septic tank is underlain by a plastic or impermeable liner. The liner is filled with sand or a fairly permeable soil. Overflow from the septic tank is introduced at the base of the sand layer. It flows up through the sand layer and flows over into the surrounding soil. The sand layer acts as a slow sand filter, where bacteria growing on the surfaces of the sand particles degrade the organic substances to reduce BOD. Because of the fluctuating flow of wastewater with peak flows in the morning and in the evening, the upper region of the sand layer alternates between aerobic and anaerobic conditions. Under these conditions a significant part of nitrogen in the wastewater can be removed by nitrification (bacterial conversion of ammonium in the wastewater to nitrate under aerobic conditions) and denitrification (bacterial conversion of nitrate to nitrogen gas under anaerobic conditions) (See also Section 2 (2.2) on Nitrogen cycle). In addition if materials that can remove phosphate are mixed with the sand, phosphorus in the wastewater is also removed. One material, that has been found to remove phosphate effectively with a capacity for phosphorus removal for several years, is bauxite refining residue (red mud).

Power is required for aeration and pumping. For a system serving a household of up to 10 persons, the power supply rating needed is 100 W (2.5 kWh per day). This on-site unit is a miniature of an activated sludge treatment plant usually used for centralised treatment (4.2.1). One difference is that surfaces are provided in the aeration tank to retain bacteria during peak flows. The other difference is that sludge from the second sedimentation tank is returned to first tank for storage.

An aerated treatment unit consists of a tank similar to a septic tank. The tank is partitioned into four compartments (Figure 2.23). The first compartment receives the wastewater and acts as a sedimentation tank for solids. The overflow from the first compartment goes to an aeration compartment. The aeration compartment is fitted with corrugated plastic sheets to enable bacteria to attach themselves. The aeration supplies oxygen to the bacteria decomposing the organic matter in the wastewater thus reducing its BOD. After aeration the wastewater passes to a third compartment which acts as a second sedimentation tank. Sludge from this second sedimentation tank is pumped to the first compartment for storage. After sedimentation the wastewater overflows to a fourth compartment for storage and pumping, usually for irrigation of garden beds. If required, chlorination is applied by inserting chlorine tablets in the pipe between the third and fourth compartments. Chlorination is required when the treated wastewater is irrigated by sprinklers. Sub-surface irrigation is preferable, because it does not require chlorination.

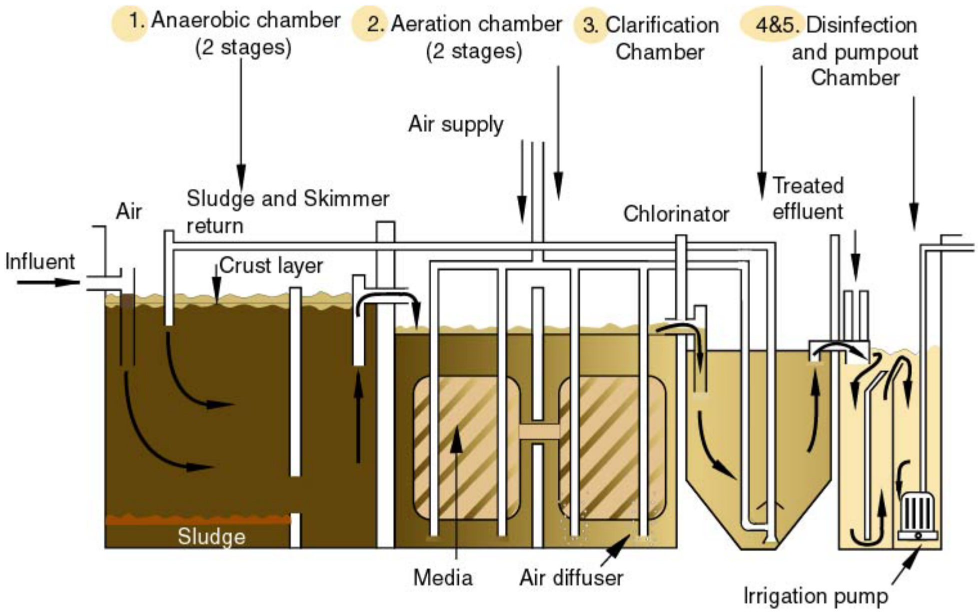


Figure 2.23: Aerated treatment unit (Biomax)

4.2 Off-site wastewater treatment systems

Off-site treatment is the treatment of wastewater that has been conveyed using a sewerage system (Section 2 (3)). Activated sludge treatment is now considered the conventional means of large-scale off-site treatment of sewage, and is described first. Trickling filtration is an alternative that was developed earlier than the activated sludge process, and this is described next. There have traditionally been other more simple, but as effective methods of treating sewage. These include the use of ponds or lagoons, land based treatment (sewage farming), and aquaculture. The first two are described in this section, while aquaculture is described under wastewater reuse (Section 2 (6)), because wastewater is generally treated first prior to aquaculture.

Several general principles common to treatment systems will be discussed first. The main aim of treatment is to reduce biochemical oxygen demand (BOD) and suspended solids (SS) to acceptable levels. This is achieved by removing solids and aerating the wastewater to satisfy the oxygen demand of the wastewater. The different treatment systems achieve the removal of solids and in providing oxygen in different ways. It should be noted that if the systems are properly designed, constructed, operated and maintained, they should all achieve the required standard of treatment. The latter is generally a reduction of BOD to less than 20 mg/L, and SS to less than 30 mg/L.

Nutrients (nitrogen and phosphorus) may need removal if the wastewater is discharged to water environments sensitive to enrichment by nutrients. The North America and Western Europe Regional Overviews contain details of methods for removing nutrients, because nutrients have been found to be a problem in many receiving waters. Heavy metals and other pollutants are not generally a problem unless the sewerage system receives industrial discharges. In this case treatment of industrial wastes prior to discharge to the sewerage system is the solution to this problem.

Removal of SS and BOD produces sludge, and the sludge has to be treated prior to reuse or disposal (Section 2 (5)). Anaerobic treatment has recently been suggested for wastewater. The main reason for the use of an anaerobic process is the recovery of energy (in the form of methane) from the wastewater (see Section 2 (2.3)) for explanation of the anaerobic process). The upflow anaerobic sludge blanket process is described at the end of this section.

4.2.1 Activated sludge treatment

The term 'activated sludge' refers to sludge in the aeration tank of an activated sludge treatment process. It consists of flocs of bacteria, which consume the biodegradable organic substances in the wastewater. Because of its usefulness in removing organic substances from wastewater, the sludge is kept in the process by separating it from the treated wastewater and re-circulating it. A typical arrangement of an activated sludge process is schematically shown in Figure 2.24.

Wastewater entering an activated sludge treatment plant is usually passed through a bar screen to remove gross materials such as napkins, rags and other materials which may damage mechanical equipment further down the treatment plant. The bar screen consists of vertical bars separated by a distance of about 1 cm. Screened solids are continually scraped off the bars. The screenings can be landfilled or incinerated.

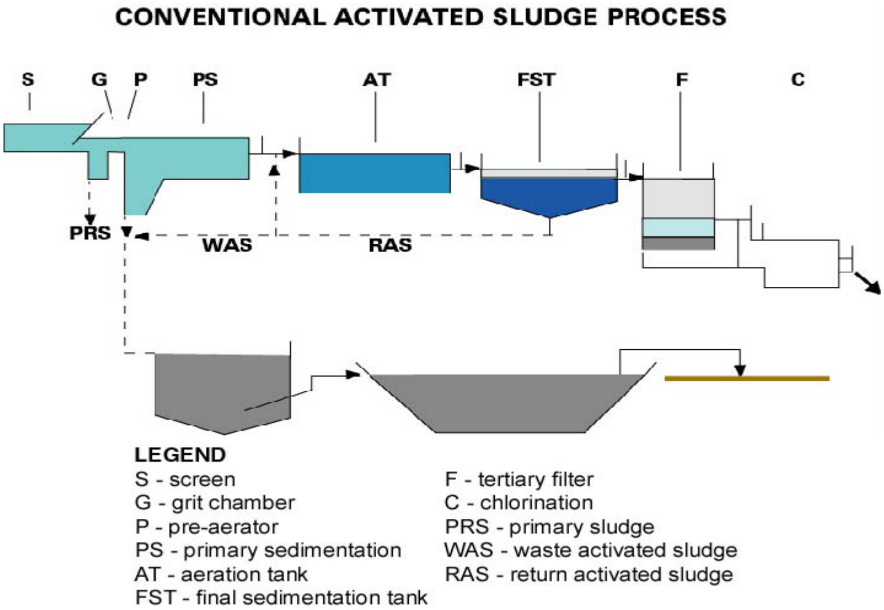


Figure 2.24: Schematic diagram of an activated sludge wastewater treatment process

Sand and similar heavy particles are removed next in a grit chamber. This chamber can be aerated to separate these particles from other suspended solids. The wastewater spends a relatively short period in the grit chamber (in the order of minutes). The sedimented sand and grit is usually landfilled.

The finer solids are removed in a settling or sedimentation tank, where the wastewater spends of the order of an hour to allow the solids to settle or float. The mechanical removal of solids as described above is usually called 'primary treatment', the sedimentation tank as primary sedimentation tank, the overflow from the sedimentation tank as primary-treated wastewater (primary effluent) and the sludge produced as primary sludge.

The primary-treated wastewater is then passed to an aeration chamber. Aeration provides oxygen to the activated sludge and at the same time thoroughly mixes the sludge and the wastewater. Aeration is by either bubbling air through diffusers at the bottom of the aeration tank, or by mechanically agitating the surface of the water.

In the aeration tank the bacteria in the activated sludge consume the organic substances in the wastewater as described in Section 2 (2.3). The organic substances are utilised by the bacteria for energy, growth and reproduction. The wastewater spends in the order of a few hours in the aeration chamber before entering a second sedimentation tank to separate the activated sludge from the treated wastewater. The activated sludge is returned to the aeration tank. There is an increase in the amount of activated sludge because of growth and reproduction of the bacteria. The excess sludge is wasted to maintain a desired amount of sludge in the system. This part of the treatment process is called 'secondary treatment', the sedimentation tank as secondary sedimentation tank, the overflow from the sedimentation tank as secondary-treated wastewater (secondary effluent) and the excess activated sludge as secondary sludge.

Depending on the flow rate of wastewater, several parallel trains of primary and secondary stages can be employed. There are several ways to operate an activated sludge process. In a 'high rate' process a relatively high volume of wastewater is treated per unit volume of activated sludge. The high amount of organic waste consumed by the activated sludge produces a high amount of excess sludge. In an 'extended aeration' mode of operation the opposite condition takes place. A relatively low amount of organic waste is treated per unit volume of sludge with little excess sludge to be removed. Removal of BOD is higher in the extended aeration mode compared to the high rate mode, but more wastewater can be treated with the latter mode.

An activated sludge treatment plant is a highly mechanised plant, and is suited to automated operation. The capital cost for building such a plant is relatively high. The energy requirement, particularly for providing air to the aeration tank, is also relatively high. There is a need for regular maintenance of the mechanical equipment, which requires skilled technical personnel and suitable spare parts. The operation and maintenance costs of an activated sludge treatment plant are therefore relatively high.

An activated sludge treatment process can be operated in batches rather than continuously. One tank is allowed to fill with wastewater. It is then aerated to satisfy the oxygen demand of the wastewater, following which the activated sludge is allowed to settle. The treated wastewater is then decanted, and the tank is filled with a new batch of wastewater. At least two tanks are needed for the batch mode of operation, constituting what is called a 'sequential batch reactor (SBR)'. SBRs are suited to smaller flows, because the size of each tank is determined by the volume of wastewater produced during the treatment period in the other tank.

4.2.2 Trickling filtration

A trickling filter is a bed of solid media for bacteria to attach on its surfaces. Wastewater is irrigated on the solid media (Figure 2.25). It is also called a biological filter to emphasise that the filtration process is not mechanical straining of solids, but removal of organic substances by use of bacterial action.

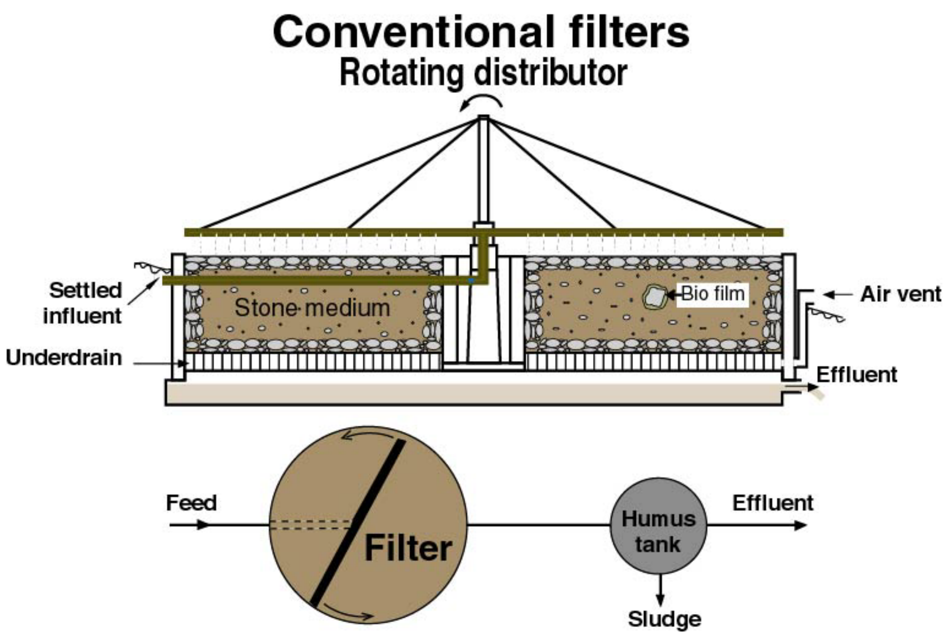


Figure 2.25: Schematic diagram of a trickling or biological filter

The solid media can be stones, waste coal gravel or specially manufactured plastic media. The latter can be corrugated plastic sheets or hollow plastic cylinders, with the main aim being to provide a large surface area for bacteria to attach to, while at the same time allowing free movement of air. Typically the solid media is placed in a tank on a support with openings to allow air to move up by natural convection and for treated wastewater to be collected in the under-drain.

Wastewater has to undergo primary treatment (See Activated Sludge Treatment above, 4.2.1) before trickling filtration, otherwise solids will block the filter. As wastewater trickles over the surfaces of the solid media organic substances are trapped in the layer of bacterial slime. The organic substances are consumed by the bacteria in the same manner as in the activated sludge process, while air diffuses into the slime layer from the air spaces in the bed of the trickling filter. Growth and reproduction of the bacteria take place and result in an increase of thickness of the slime layer, particularly at the top of the biological filter. Periodically bacterial slime sloughs off the surfaces of the filter media and leaves with the treated wastewater.

Solids derived from the sloughing off of bacterial slime are separated from the treated wastewater in a sedimentation tank. Sludge from this sedimentation tank is not returned to the trickling filter, but treated prior to reuse or disposal (Section 2 (6)). Treated wastewater can however be returned to the trickling filter, if this will assist with either treating the wastewater further (second pass) or more generally for a more uniform distribution of water over the trickling filter bed. The trickling filter and associated sedimentation tank is also termed 'secondary treatment'.

The energy requirement for operating a trickling filter is less than for an activated sludge process, because oxygen supply to the bacteria is provided by natural diffusion of air. The area requirement of a biological filter is, however, larger than for an activated sludge process to achieve the same quality of treated wastewater.

4.2.3 Lagoons

Ponding or lagooning is effective in treating wastewater and can reduce BOD and SS to the same levels as mechanical treatment plants (e.g. Activated Sludge Treatment). In addition because of the longer residence time of wastewater in the lagoon (in the order of days), removal of pathogenic bacteria and viruses by natural die-off is greater than in an activated sludge treatment plant (residence time of the order of hours). Cysts of parasites and helminth eggs are also usually removed through sedimentation in the lagoons.

A lagoon is a shallow excavation in the ground (1 to 2 m deep). It is generally unlined and percolation of wastewater into the soil and groundwater takes place. With time the percolation rate will reduce, because of formation of a sediment layer. Evaporation loss of water can be significant in arid climate regions. The soil itself is, however, not involved in the physical and biochemical wastewater treatment processes taking place in the lagoon. A lagoon can therefore be lined with a layer of clay or with an impermeable plastic membrane if protection of groundwater is desired, without affecting the performance of the lagoon. Wastewater lagoons are also called 'waste stabilisation lagoons', because the organic substances in the wastewater are converted to more stable (less degradable) forms.

The following processes take place in a lagoon. As wastewater enters a lagoon sedimentation of solids occurs. Because of the long residence time of the wastewater in the lagoon system, much of the solids in the original wastewater are removed. Aeration of the water from the atmosphere occurs by a process of diffusion aided by turbulence caused by wind movement on the surface of the water. This process is the same as the natural process of aeration of a lake described in Section 2 (2.2).

Oxygen is also supplied by algae in the lagoon which thrive on the nutrients (nitrogen and phosphorus) released by the decomposition of the organic wastes. The photosynthetic activity of algae, however, only takes place when there is sunlight. Thus oxygen produced by photosynthesis is only available during this period. A symbiotic relationship exists between the bacteria and the algae. Bacteria take up oxygen and release carbondioxide, while algae take up carbondioxide released by the bacteria and produce oxygen for the bacteria (Figure 2.26).

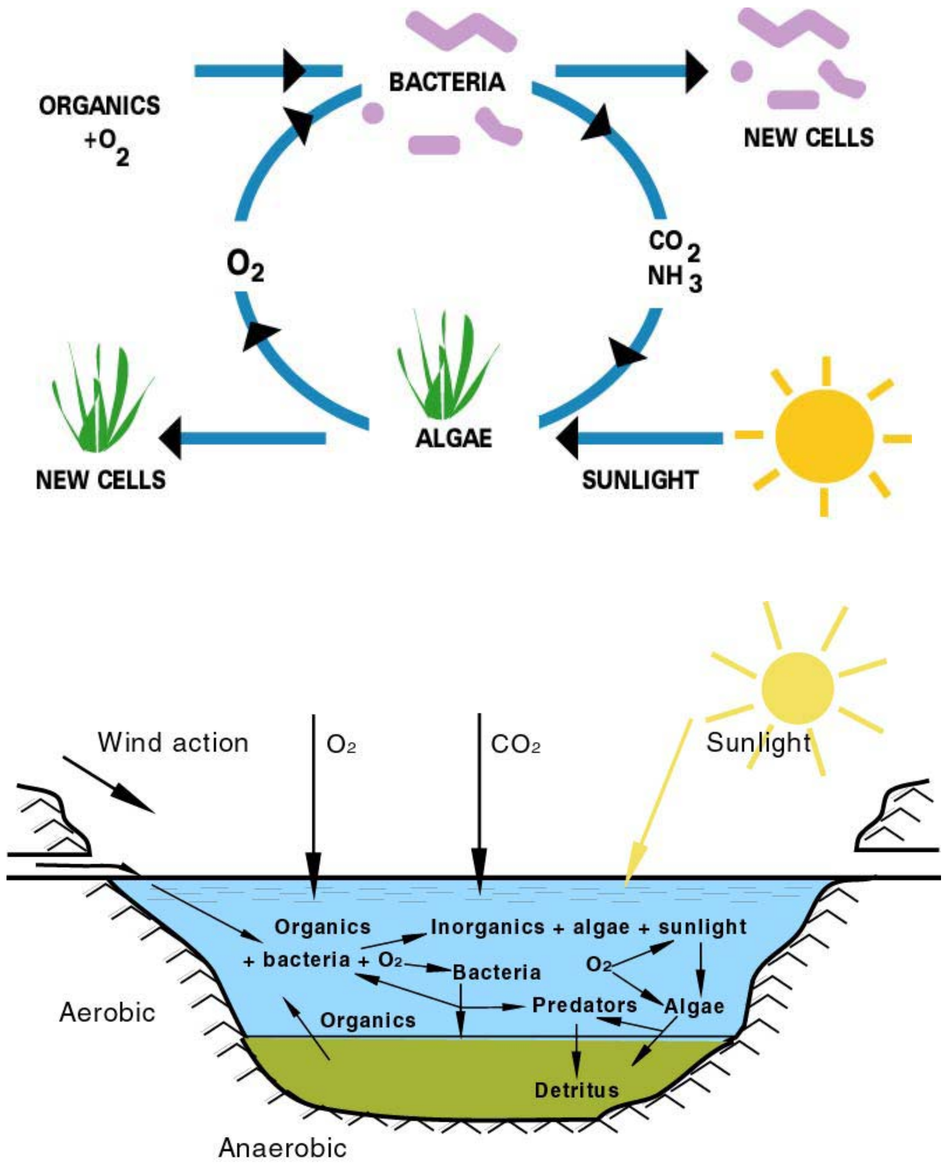


Figure 2.26: Symbiotic relationship between bacteria and algae in a wastewater lagoon

Depending on the oxygen demand of the bacteria in the lagoon, the following conditions occur:

Anaerobic lagoon	The oxygen demand of the bacteria exceeds oxygen supply by surface aeration and algal photosynthesis. Biodegradation of the organic wastes is by anaerobic bacteria. Methane gas is a by-product (Section 2 (2.3)). Odorous gases are produced, but impact is reduced when a layer of scum forms at the water surface.
Facultative lagoon	The oxygen demand of the bacteria is met by surface aeration and algal photosynthesis, but is not met when the latter is not active. The water environment is aerobic during the day, but turns anaerobic at night. Biodegradation of organic wastes is by facultative bacteria, which can operate under both aerobic and anaerobic conditions.
Aerobic lagoon	The oxygen demand of the bacteria is met by surface aeration and algal photosynthesis.

It is common to have a series of lagoons with the first one or two being anaerobic lagoons, the middle ones facultative lagoons and the last few aerobic lagoons. The sediment at the bottom of lagoons is anaerobic, and undergoes anaerobic bacterial decomposition. The first lagoon in a series will eventually be filled with solids. The sludge produced can be removed and treated for re-use or disposal (Section 2 (6)) or allowed to undergo further biodegradation in the lagoon prior to re-use. Anaerobic lagoons can be made deeper so that more sludge can be accommodated and the need to remove sludge made less frequent.

Lagoon performance is affected by temperature. At a higher ambient temperature (e.g. in the tropics) a shorter residence time of wastewater in the lagoon is required to achieve the same level of treatment compared to when the temperature is lower. Because algae are present in treatment lagoons, they leave with the treated effluent. One way of harvesting the algae is through aquaculture (see Section 2 (6)).

Oxygen transfer from the atmosphere into lagoons can be increased by mechanically agitating the surface of the water. This can be done by using a vertically mounted impeller, and the lagoon becomes more like the aeration tank of an activated sludge process. The agitation can also be provided using a horizontally mounted rotor. A configuration that can be used to apply this is a circular ditch (Figure 2.27), and the water is continuously circulated around the ditch so that its movement is like that in a river.

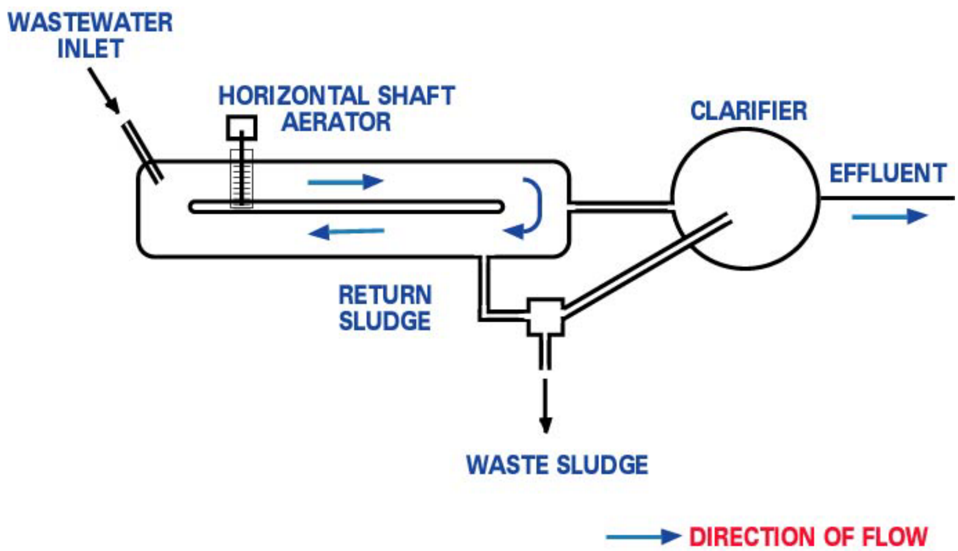


Figure 2.27: Oxidation ditch

4.2.4 Land based treatment

Land based treatment of wastewater relies on the action of soil bacteria to degrade the organic wastes in the wastewater. In what is termed 'Soil Aquifer Treatment' wastewater is applied to unlined basins in cycles of flooding and drying of approximately one week each (Figure 2.28). During flooding wastewater percolates through the soil beneath the basin to the unconfined groundwater aquifer. Organic substances are consumed by soil bacteria. Suspended solids are trapped at the bottom of the basin, and the percolation rate decreases. During drying the layer of solids accumulating at the bottom of the basin are degraded by bacteria and also undergo drying. The percolation capacity for wastewater is therefore rejuvenated.

Soil aquifer treatment is also known as rapid-rate land application. It works well when the soil permeability is high (> 1 m/day), and the highest groundwater table is at least 2 m below the bottom of the basin. Upon reaching the groundwater the SS and BOD of the water is generally low. Furthermore if the soil beneath the basin contains clay minerals, pollutants like heavy metals may be adsorbed by the clay minerals. The groundwater aquifer acts as a storage for the treated wastewater, which is usually withdrawn for reuse.

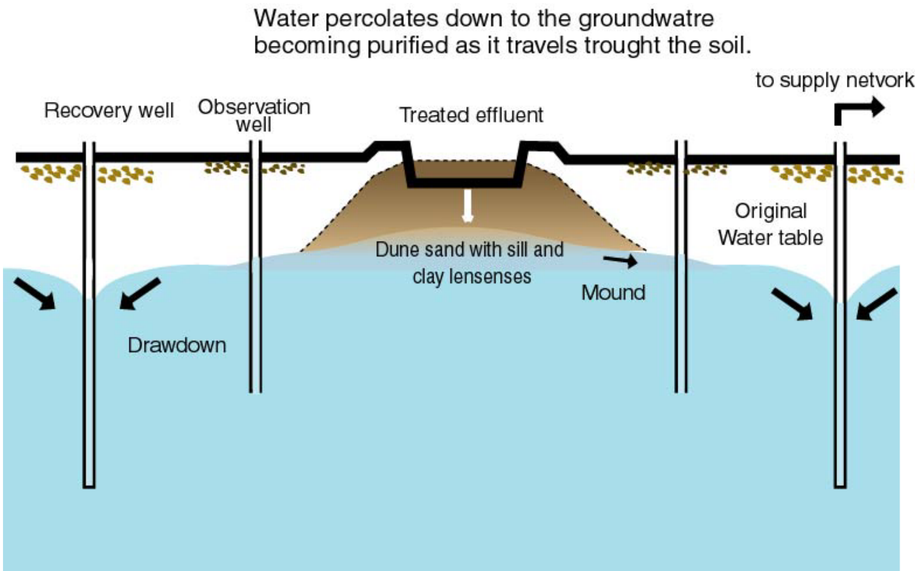


Figure 2.28: Soil aquifer treatment or rapid-rate land application system

In what is termed 'slow-rate land application system' wastewater is applied to land through channels in the upper part of the gradient and treated wastewater is collected in channels in the lower part of the gradient of a slightly inclined ground (Figure 2.29). The application is intermittent and its rate is dependent on the permeability of the soil and the loss of water due to evaporation. The organic substances in the wastewater are biodegraded by soil bacteria at the surface of the soil and during percolation through the soil. Vegetation is usually part of the treatment process. It takes up nutrients (nitrogen and phosphorus) released from the degradation of the organic substances. The vegetation (usually grasses) is harvested by grazing animals (cattle or sheep). Note that in New Zealand the successful disposal of treated wastewater has been achieved by spray irrigated into forests and for crops growth. Again the trees and crops take up the disposed nutrients and use then to promote growth. This is mainly for disposal purposes and not for re-uses. Crops (usually grass) are harvested as silage and then fed to live stock. This disposal system is referred to as “cut and carry” for the livestock do not graze the irrigated paddocks. The silage is of good quality and there is a demand for it. Sub-surface irrigation disposal of wastewater for silage is also being promoted.

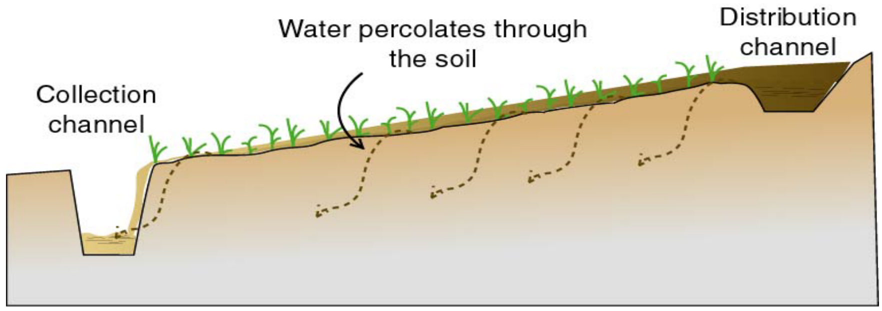


Figure 2.29: Slow-rate land application system

When the soil is saturated with water (e.g. during the rainy season), 'overland flow' or 'grass filtration' mode of operation is used. In this case wastewater flows over the soil surface and the organic substances are removed by bacteria attached to the vegetation and soil surface (Figure 2.30).

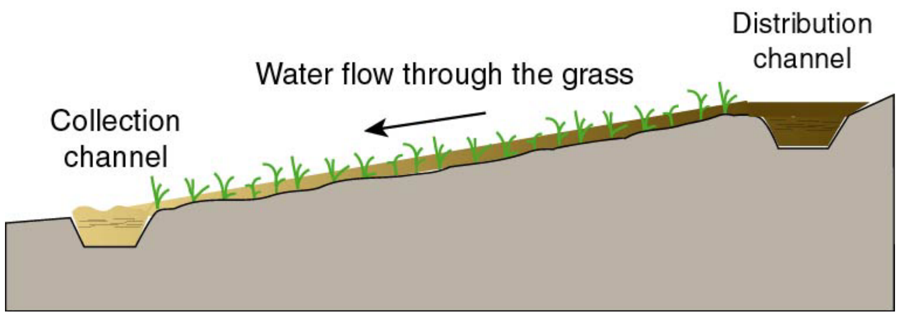


Figure 2.30: Grass filtration

Raw wastewater can be used in any of the above land based treatment system provided that the application rate is small. Settled wastewater needs to be used for higher rates of application. Land application treatment systems work well in arid or semi-arid regions, where the soil is generally not saturated with water over much of the year, and reuse of wastewater for agriculture is attractive. Particular attention has to be given to public health requirements (see Section 2 (6)).

4.2.5 Constructed wetlands

Constructed wetlands are in-between lagoons (4.2.3) and land based treatment systems (4.2.4). A constructed wetland consists of a gravel bed in which wetland species, such as reeds, are planted (Figure 2.31). Wastewater (usually after settling of solids) passes through the gravel bed, and organic substances are degraded by bacteria attached to the surfaces of the bed and plant roots. The removal of BOD and SS in beds with and without plants does not appear to differ by very much. Wetland plants take up nutrients (nitrogen and phosphorus) when water residence time is long. Long-term nutrient removal requires harvesting of the plants. Constructed wetlands need to be designed to minimise problems with insects (mosquitoes and midges).

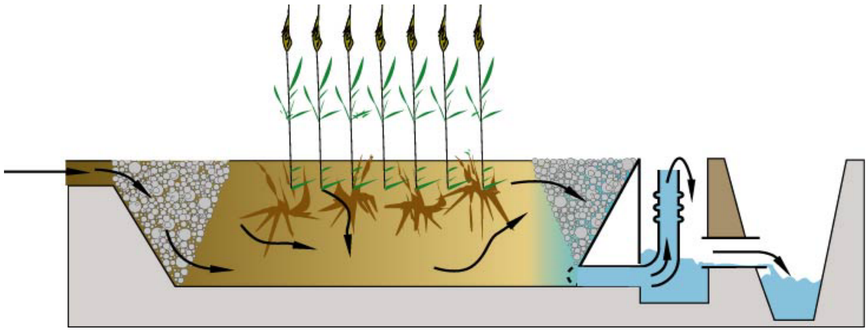


Figure 2.31: Constructed wetland

4.2.6 Anaerobic treatment of wastewater

Anaerobic treatment is more suited to wastewater high in BOD. It is used to treat the sludge from an activated sludge treatment or biological filtration process (see Section 2 (5)). In households where there is cottage industry (such as food processing to supply restaurants or food market) the wastewater may be high in BOD. Wastewater high in BOD may also be generated when water conservation measures result in less water being used. A simple method to treat blackwater and kitchen waste is shown in Figure 2.32. The biogas produced can be combusted for use in cooking.

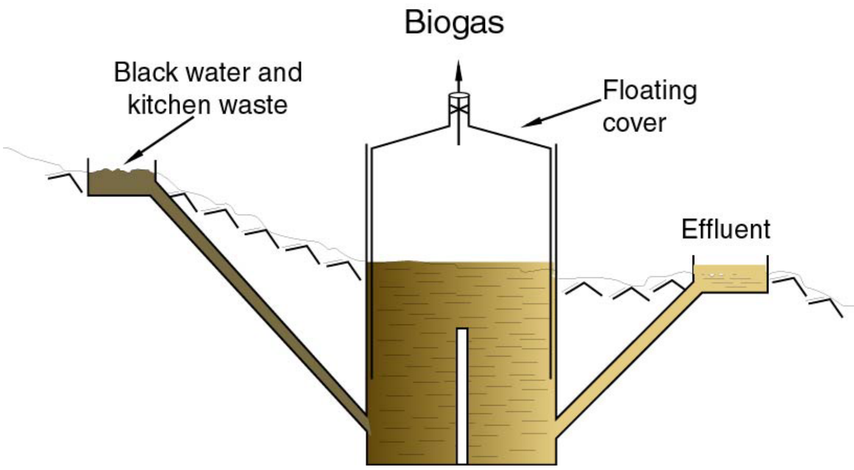


Figure 2.32: A simple anaerobic treatment of blackwater and kitchen waste

In the Upflow Anaerobic Sludge Blanket (UASB) process settled wastewater is passed upward through a sludge blanket. The sludge blanket consists of anaerobic bacteria, which have developed into granules. Because of the high settling velocity of the granules, the granules are not carried over in the upflowing wastewater. A high concentration of bacteria is therefore retained in the tank. The tank itself has no internal moving parts (Figure 2.33). If wastewater is distributed evenly at the base of the tank, mixing between the wastewater and the granules of bacteria is promoted by the carbondioxide and methane gases produced by the anaerobic treatment process and the upward moving flow of the wastewater.

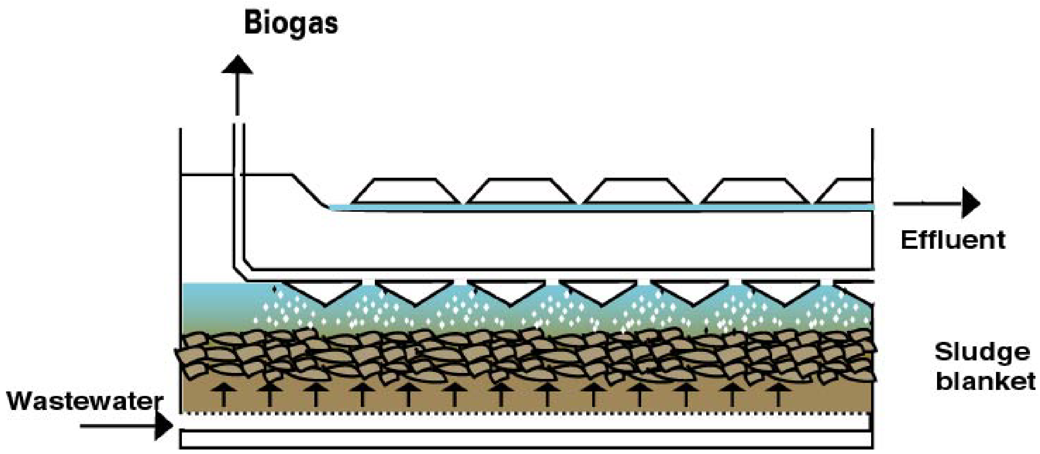


Figure 2.33: Upflow anaerobic sludge blanket (UASB) reactor

Although the reactor itself has a simple configuration with no moving parts, pumping of the feed is still required. Methane gas is produced which needs special handling procedures to prevent leakage and explosion. Wastewater treated anaerobically requires further aerobic treatment to reduce its BOD and odour. Excess granules need to be treated prior to reuse or disposal, although currently there is a demand for the granules to start up UASB reactors. The mixture of methane and carbon dioxide (termed 'biogas') can be combusted and used for heating the content of the anaerobic reactor or for other purposes.

4.3 Stormwater treatment

Stormwater can be polluted as discussed in Section 2 (2.1). When collected in a combined sewerage system it is treated with the wastewater, though treatment is not effective during peak heavy stormwater run-off periods resulting in combined sewer overflow (CSO) that is not treated. Storage basins or tanks can be used to accommodate moderate peak flows of combined stormwater and wastewater, and treating the stored water at night when wastewater flow is a minimum. The Regional Overview for Western Europe devotes a full sub-section on CSO.

Separately collected stormwater is generally treated by passing it through a settling basin to remove solids (Figure 2.34). The retention time in the settling basin is designed so that solids can settle in say 20 minutes for a one in five year storm-event. For storm-events less than the design value removal efficiency is greater, while for storm-events greater than the design value removal efficiency is lower. Mechanical devices have been developed that can trap gross solids (see North American RO). Both settling basins and mechanical traps need to be cleaned regularly to maintain solids removal efficiency.

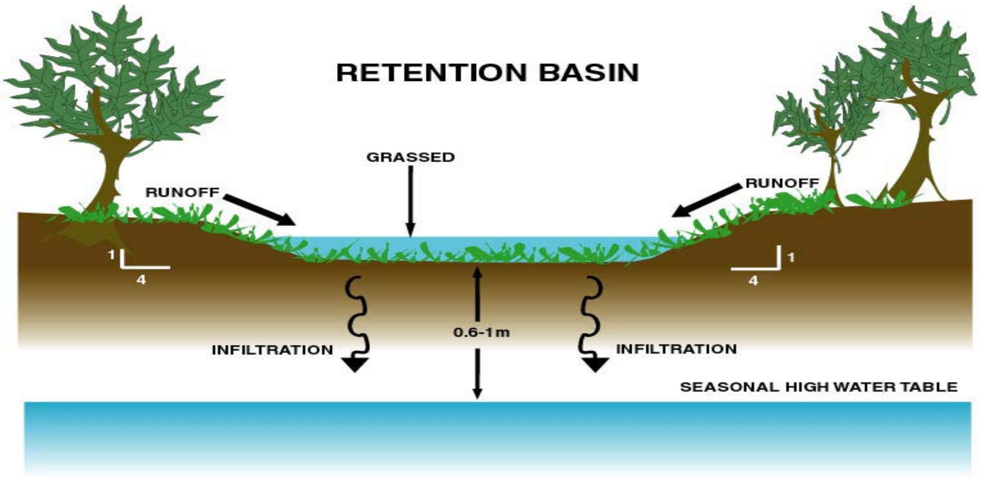


Figure 2.34: Stormwater treatment by settling

Naturally landscaped stormwater drains can help filter out fine sediments through the action of vegetation slowing down the flow and trapping solids. Permeable surfaces allow rainwater to percolate into the soil, thus treating the water in much the same manner as land based treatment of wastewater (4.2.4.) and at the same time reduce the amount of run-off. Pavements have been designed and manufactured for this purpose. Directing run-off to vegetated area (rainwater harvesting) can reduce down-stream flow and reuse the water for maintaining plant growth. This is especially beneficial in arid climates. Four techniques for stormwater treatment are described below. Used judiciously these can treat stormwater locally (at source, Figure 2.35). Applying these on a sub-catchment scale (site), or whole catchment scale (region) can reduce flooding and the undesirable impacts of stormwater described in Section 2 (2.1), while at the same time improve the amenity value of the landscape through creation of, for example, passive recreation water bodies.

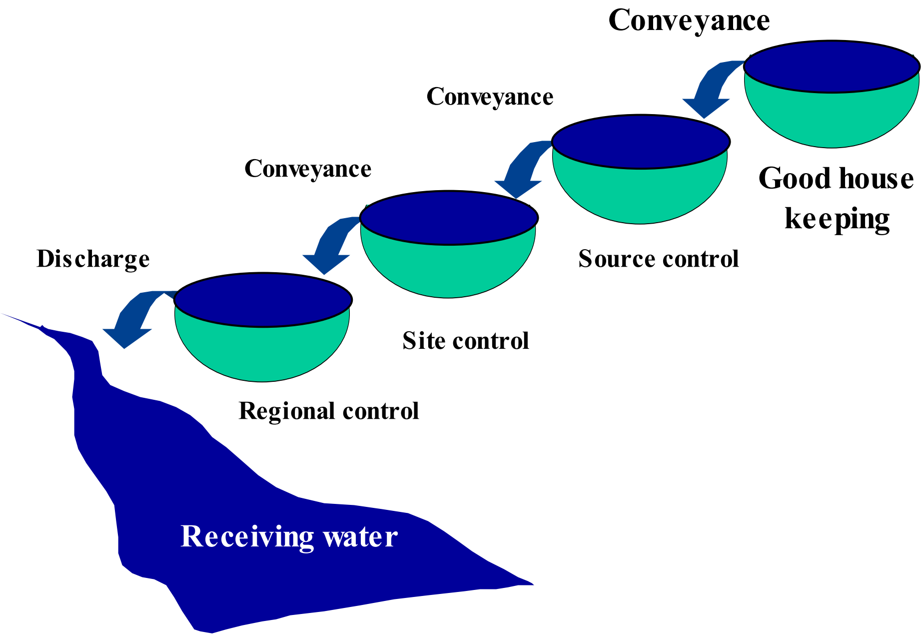


Figure 2.35: Management train for stormwater at the local, sub-catchment and catchment levels

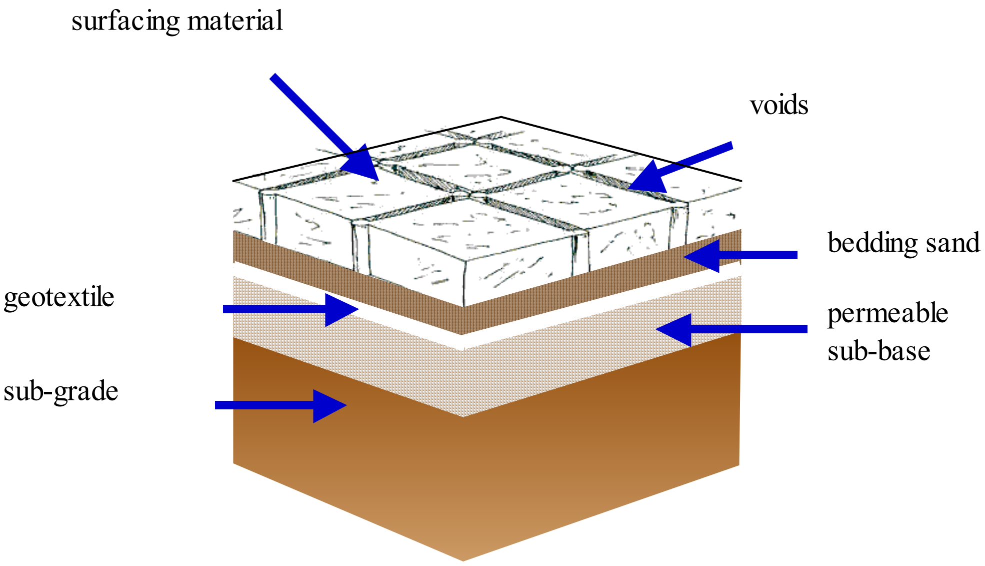
4.3.1 Filter strips and swales

Filter strips and swales are vegetated surface features that drain water evenly off impermeable areas (Figure 2.36). Swales are long shallow channels, while filter strips are gently sloping areas of ground. They allow run-off to flow in sheets through vegetation, slowing and filtering the flow. Swales also act to temporarily store and infiltrate the run-off into the ground. Sediments are removed from the water, and vegetation can take up any nutrients in the water. Swales and filter strips can be integrated into the surrounding land use, for example road verges. Local grasses and flower species can be introduced for visual effect and to provide a wildlife habitat. Maintenance consists of regular mowing, clearing litter and periodic removal of excess silt.

Figure 2.36: Filter strip and swale in an urban landscape

4.3.2 Filter drains and permeable surfaces

Filter drains consist of permeable materials located below ground to store run-off. Run-off flows to the storage area via a permeable surface (Figure 2.37). The permeable surface can be in the form of grassed or gravelled areas, paving blocks with gaps between individual units or paving blocks with vertical voids built in. Water is therefore collected from a large surface area, stored in the filter drains and allowed to infiltrate through the soil. The permeable fill traps sediments and thereby clean the run-off. Filter drains and permeable surfaces are currently used for road verges and car parks. The surfaces should be kept clear of silt and cleaned regularly to keep the voids clear. Weed control may be necessary.



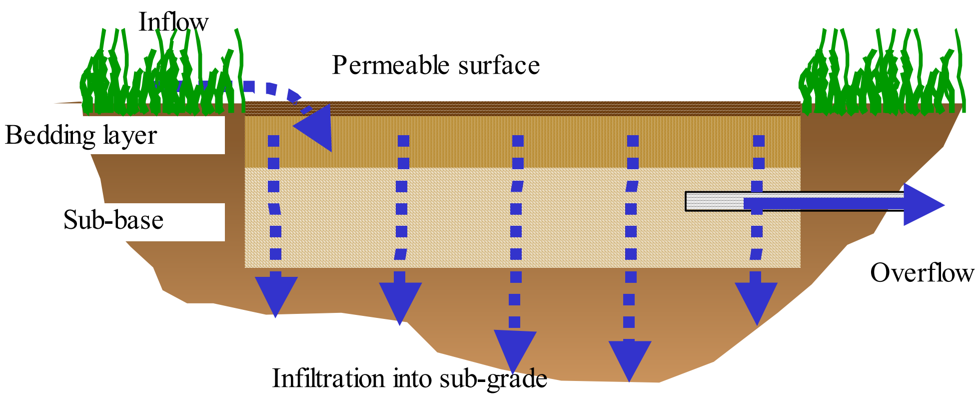


Figure 2.37: Permeable pavements

4.3.3. Infiltration devices

Infiltration devices drain water directly into the ground. They include soakways and infiltration trenches, which are located below ground, and into which stormwater run-off is directed. They function by storing water and allowing the water to infiltrate into the ground. Figure 2.38 shows a cross-section through a traditional soakway or a chamber soakway. They work well when the soil is permeable and the groundwater table is not close to the surface. Maintenance consists of regular inspection to ensure the infiltration capacity is maintained. Areas draining to an infiltration device should be kept clear of silt, as this will get washed into the device and reduce its permeability as well as filling up space that should be used for storage.

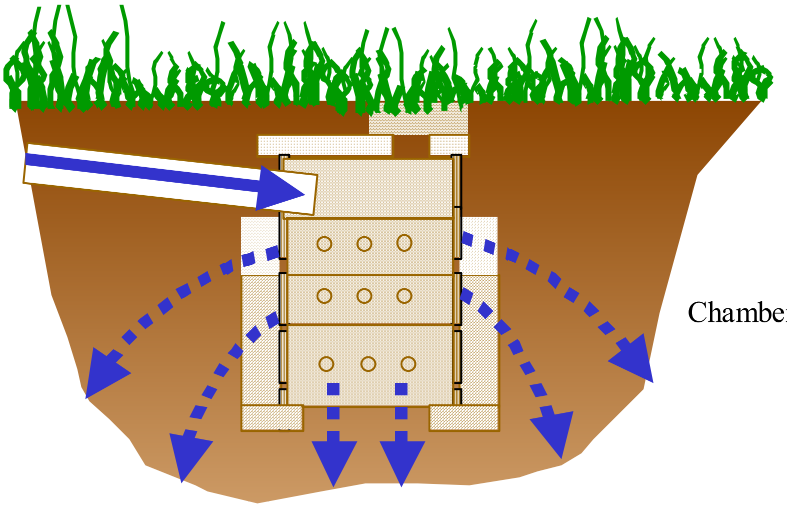


Figure 2.38: Cross-section through a traditional soakway or a chamber soakway (CIRIA, 1999)

4.3.4 Basins and ponds

Basins are areas for storage of run-off that are dry during dry weather, whereas ponds have permanent water (Figure 2.39). Both act to store water and therefore attenuate the flow of water during a storm. Flow downstream of the basins or ponds can therefore be controlled. Basins and ponds also act as infiltration devices (Section 4.3.3). Basins and ponds are usually used at the end of a train of treatment for stormwater, and provide additional step if source control (Sections 4.3.1 to 4.3.3) does not have an adequate capacity to control run-off. Detention time is of the order of two to three weeks. Both basins and ponds can be vegetated, so that we can have a range of features, including wetlands that have amenity values for passive recreation or wildlife habitat. Run-off water quality is improved upon storage in basins or ponds because of sedimentation of solids, bacterial action and nutrient uptake by vegetation. Water stored in ponds can also be used for irrigation of parks and gardens or for fire-fighting and other purposes. Basins and ponds need to be maintained to control vegetation and removal of accumulated silt.

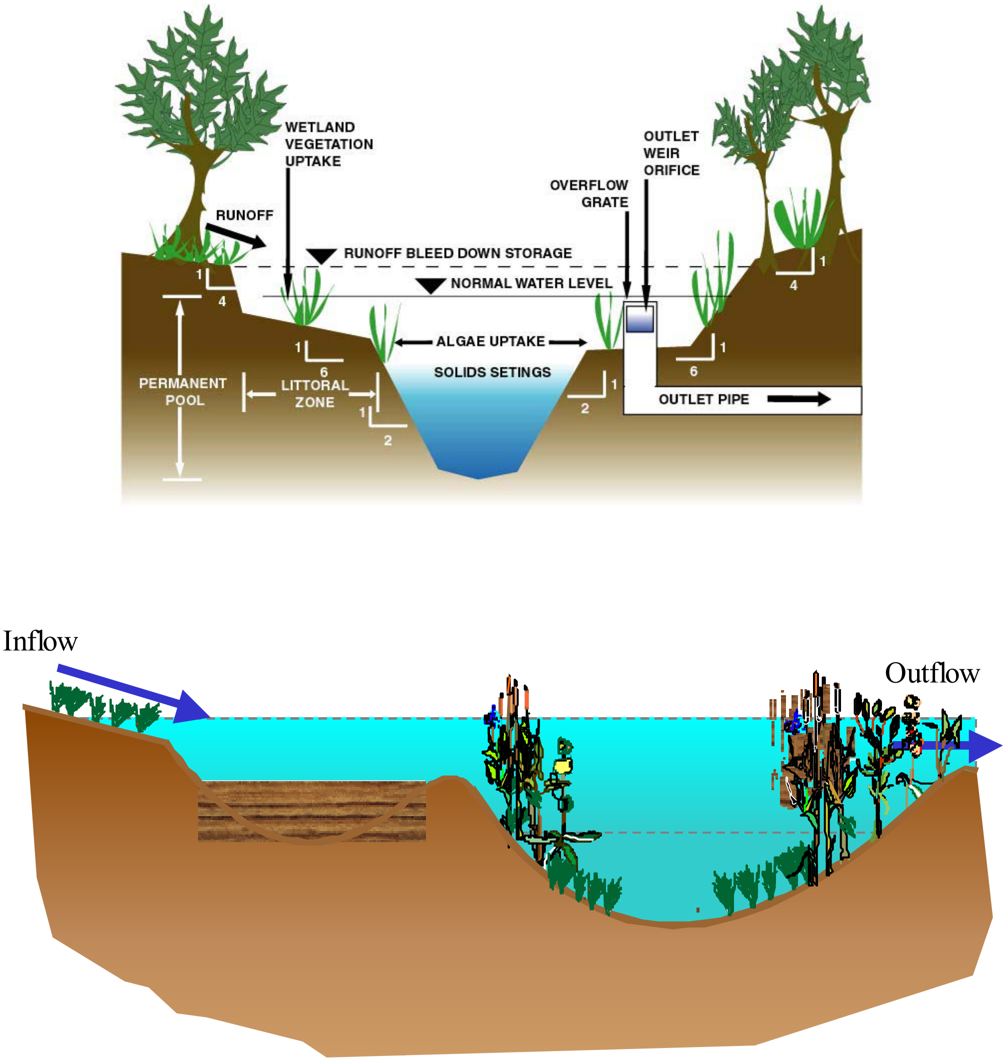


Figure 2.39: Pond, basin and constructed wetland for stormwater treatment

5. Sludge treatment, reuse and disposal

Sludge is produced from the treatment of wastewater in on-site (e.g. septic tank) and off-site (e.g. activated sludge) systems. This is inherently so because a primary aim of wastewater treatment is removing solids from the wastewater. Additionally soluble organic substances are converted to bacterial cells, and we remove the latter from the wastewater. Sludge is also produced from the treatment of stormwater (Section 4.3), although it is likely to be less organic in nature compared to wastewater sludge.

Bucket latrine and vault latrine store faecal sludge, which needs to be collected and treated. These two types of latrine are not discussed in Section 2 (4), because no treatment is involved at the latrines. In the former case human excreta is deposited in a bucket and the content of the bucket is emptied daily, usually at night giving the term ‘night soil’ to the faecal sludge. In the latter the excreta is stored in a vault for a longer period of up to two weeks before removal. The content of the vault should preferably be removed mechanically.

The characteristics of sludge vary widely from relatively fresh faecal materials generated in bucket latrines to sludge which has undergone bacterial decomposition for over a year in a double pit latrine. The treatment required is therefore dependent on the characteristics of the sludge. The former may contain large numbers of pathogens, whereas the latter will contain much less due to pathogen die-off. Sludge should, however, always be handled with care to avoid contact with pathogens.

Sludge may be contaminated with heavy metals and other pollutants, especially when industrial wastes are disposed into the sewer. Pre-treatment of industrial wastes is therefore essential before discharge to the sewer. Treatment of sludge contaminated with high concentrations of heavy metals or toxic chemicals will be more difficult and the potential for re-use of the sludge will be limited.

Faecal sludge contains essential nutrients (nitrogen and phosphorus, Section 2 (2)) and is potentially beneficial as fertilisers for plants. The organic carbon in the sludge, once stabilised, is also desirable as a soil conditioner, because it provides improved soil structure for plant roots.

Options for sludge treatment include stabilisation, thickening, dewatering, drying and incineration. The latter is most costly, because fuel is needed and air pollution control requires extensive treatment of the combustion gases. It can be used when the sludge is heavily contaminated with heavy metals or other undesirable pollutants. Prevention of contamination of the sludge by industrial wastes is preferable to incineration. A conversion process to produce oil from sludge has been developed, which can be suitable for heavily contaminated sludge (S. Skrypsi-Mantele, T.R. Bridle, P. Freeman, A. Luceks and P.D. Ye, 2000).

The costs of treatment of sludge are generally of the same order as the costs of removing the sludge from the wastewater.

5.1 Stabilisation

Faecal sludge collected from bucket or vault latrines has a very high biochemical oxygen demand (BOD) and is generally putrid and odorous. Primary and secondary sludges from an activated sludge treatment plant also have a high BOD and may be difficult to dewater. Even sludge from a septic tank, which has undergone bacterial decomposition over at least a year, still has a high BOD. Stabilisation is the term used to denote the process of BOD reduction. The stabilisation process can be carried out under aerobic or anaerobic conditions. The corresponding bacterial processes are described in Section 2 (2.3).

Aerobic stabilisation of primary and secondary sludges can be carried out in an aeration tank in the same manner as in an activated sludge process. Because of the high oxygen requirement this process is energy intensive and costs are high. Aerobic stabilisation requires less energy when carried out as part of a composting process. For composting of sludge, its solids content should be increased to at least 15 % so that it can be handled as a solid. Thickening and dewatering (see below) of primary and secondary sludges are required to achieve the required solids content. Faecal sludge may contain high enough solids. Mixing with dry materials such as dry saw dust may assist with achieving the required solids content as well attaining the required carbon to nitrogen ratio for composting.

5.2 Composting

Composting is an aerobic bacterial decomposition process to stabilise organic wastes and produce humus (compost). Compost contains nutrients and organic carbon which are excellent soil conditioners. Composting takes place naturally on a forest floor where organic materials (leaf litter, animal wastes) are converted to more stable organic materials (humus) and the nutrients are released and made available for plant uptake (Section 2 (2.2)). The process is slow on a forest floor, but can be accelerated under optimum conditions.

The optimum conditions for composting are a moisture content of about 50 %, a carbon to nitrogen ratio of about 25 to 30, and temperature of 55 ^{o}C. Because wastewater sludge is rich in nutrients its carbon to nitrogen ratio is low (5 to 10). It is also high in moisture. Addition of dry saw dust, which is very high in carbon to nitrogen ratio (500) can adjust both the moisture and carbon to nitrogen ratio. Other waste materials that can be used for this purpose are mulched garden wastes, forest wastes and shredded newspaper.

Composting can be carried out in a specially built composter, such as an inclined rotating cylinder, fed on one end with the raw materials, and the aerated product collected at the other end. As the materials are slowly tumbled over a period of about one week, they are mixed and aerated. Because bacterial decomposition produces heat, temperatures in the insulated composter can easily reach 55 ^{o}C. The immature compost is then windrowed for at least 12 weeks to allow the composting process to complete, with occasional turning of the windrow.

Composting can be more simply carried out in windrows (Figure 2.40). Regular turning of the windrows assists with mixing of the materials and more importantly supply the oxygen to the bacteria. Temperatures can reach 55 ^{o}C, because compost has a good heat insulating property. Turning of the compost also ensures that all parts of the windrow reach the required 55 ^{o}C essential for pathogen destruction. Turning is required every two to three days in the first two weeks when temperature is 55 ^{o}C or above. After this period frequent turning of the compost windrow is not required as less heat is generated and less oxygen is required while the compost undergoes maturation.

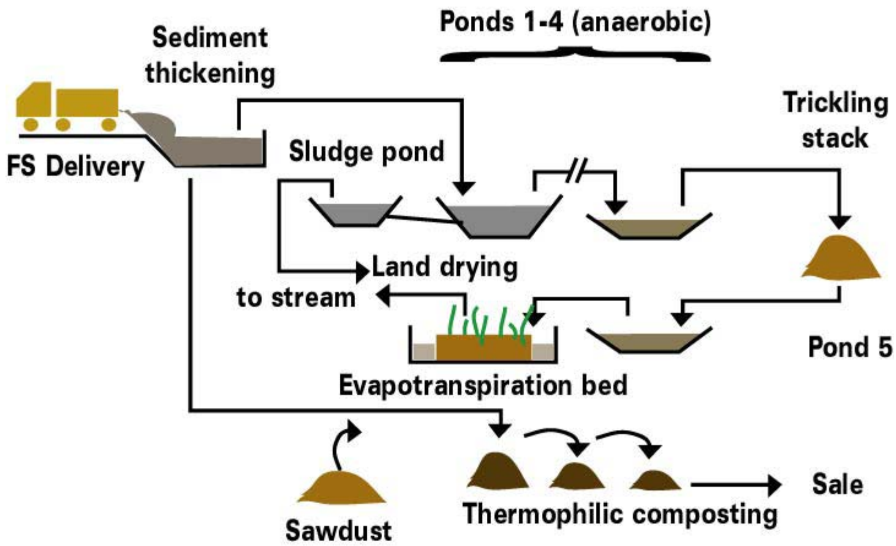


Figure 2.40: Windrow composting of faecal sludge (FS) (from Heinss et al., 1999)

5.3 Anaerobic digestion

Anaerobic digestion is a bacterial decomposition process which stabilises organic wastes and produces a mixture of methane and carbon dioxide gas (biogas). The heat value of methane is the same as natural petroleum gas, and so biogas is valuable as an energy source.

Anaerobic digestion is usually carried out in a specially built digestor, where the content is mixed and the digestor maintained at 35 ^{o}C by combusting the biogas produced. After digestion the sludge is passed to a sedimentation tank where the sludge is thickened. Biogas is collected from the digestor (Figure 2.41). The thickened sludge requires further treatment prior to reuse or disposal.

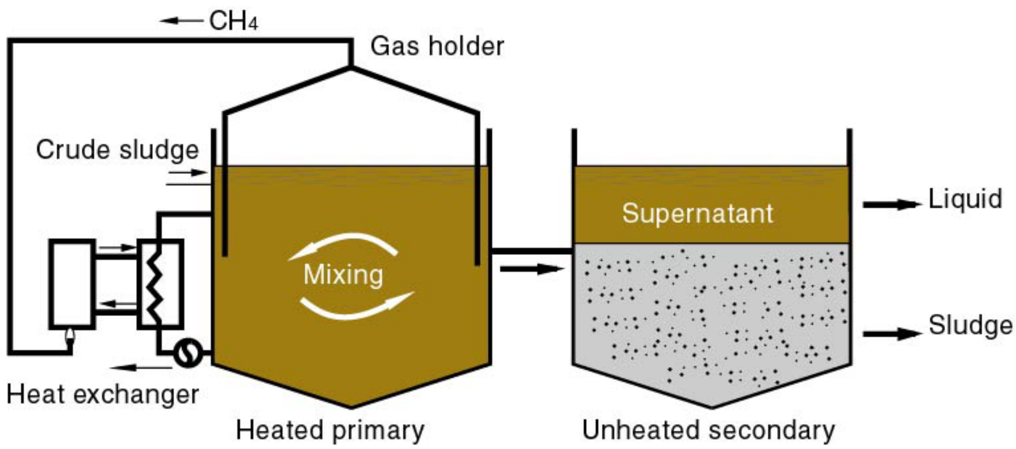


Figure 2.41: Simple anaerobic digestion process

Anaerobic digestion can also be carried out at a slower rate in an unmixed tank or pond. Covering is usually by a UV resistant plastic sheet, because of the large area needed to be covered, and biogas is collected from the top of the sheet.

Storage of biogas can be in a cylindrical tank with a floating roof. The cylindrical roof floats on water and its position is determined by the volume of the gas stored under the pressure of the roof. Biogas can also be stored in a balloon, but only under low pressure.

5.4 Thickening

Sludge contains a high concentration of solids, but its water content is still high. Combined primary and secondary sludge from an activated sludge treatment plant contains about 2 % solids and hence 98 % water. One kg of dry sludge is associated with 49 L of water. Thickening to 5 % solids means one kg of dry solids is associated with 19 L of water, thus 30 L of water has to be removed.

Thickening is carried out in a sedimentation tank or in a sedimentation pond (Figure 2.42). The latter is advantageous if land area is available, because the sludge can be allowed to settle over a much longer period and a higher solids content of the thickened sludge is achieved. The water removed from thickening needs treatment. It can be returned to the inlet of an off-site wastewater treatment plant, or in the case of sludge from on-site units by an aerobic treatment process such as lagooning.

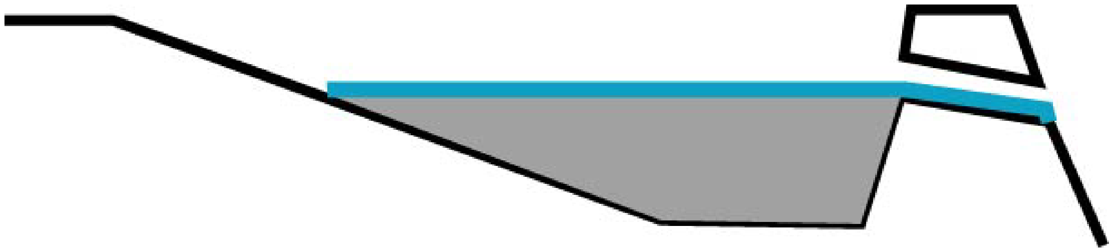


Figure 2.42: Sludge thickening pond (Ghana) (Heinss et al., 1999)

5.5 Dewatering and drying

Dewatering aims to reduce the water content further so that the solids content of the sludge is about 20 % (equivalent to 1 kg dry sludge with 4 L of water). The sludge can then be handled like a solid. Dewatering can be done mechanically using a filter press (employing pressure or vacuum), or a centrifuge. It can also be done using drying beds. A drying bed consists of a 30 cm bed of sand with an under-drainage (Figure 2.43). Sludge is applied on the sand bed and is allowed to dry by evaporation and drainage of excess water over a period of several weeks depending on climatic conditions. Bacterial decomposition of the sludge takes place during the drying process while moisture content is sufficiently high. During the rainy season the process may take a longer time to complete, and sizing the area of the drying beds should take this into account.

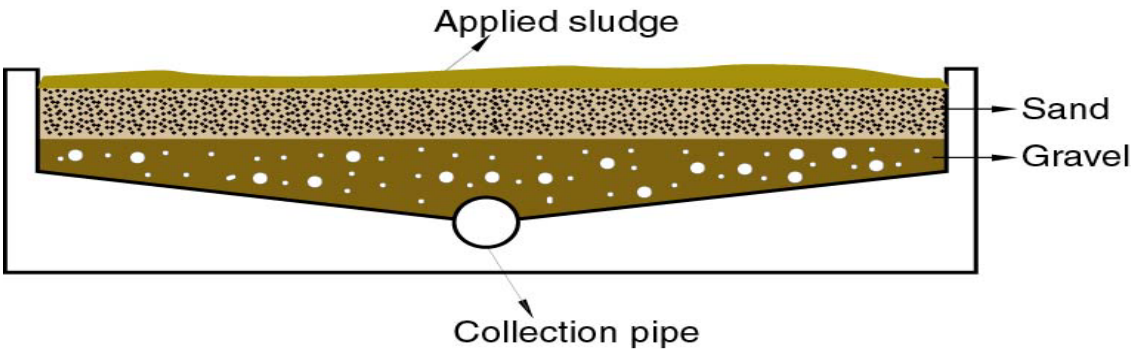


Figure 2.43: Sludge drying bed

5.6 Sludge reuse

Raw sludge from activated sludge treatment plants has been applied directly onto agricultural land particularly in the United Kingdom. This practice is considered unsatisfactory because of the presence of pathogens in the sludge in high numbers. There has been no thorough study, however, which has shown that there is an increase in the risk of acquiring illnesses associated with pathogens in the raw sludge when proper handling procedure and non-entry to the land following application is observed.

Reuse of composted sludge as a soil conditioner in agriculture and horticulture returns carbon, nitrogen, phosphorus and elements essential for plant growth back to the soil (Section 2 (2.4)). Less chemical fertilisers are required and the organic carbon helps to improve soil structure for soil aeration, water percolation and root growth. The nitrogen and phosphorus are also released gradually for plant uptake compared to the more soluble chemical fertilisers. The potential of leaching of the nutrients to ground or surface water by rainfall run-off is much reduced. Pathogens and heavy metals can, however, limit the reuse of sludge.

Pathogens should be reduced to levels that do not pose health hazards to workers handling the sludge, potential health hazards from the spreading of helminth eggs and from horticultural produce contaminated by pathogens. Composting of the sludge to attain a temperature of 55 ^{o}C for two weeks followed by windrow maturation produces compost that meets these conditions. Stabilised sludge which has been dewatered and dried on sand beds to attain a low moisture content can meet the same conditions.

Heavy metals and toxic chemicals are difficult to remove from sludge. Preventing these chemicals from entering the wastewater or sludge should be the aim of wastewater management for sludge intended for reuse in agriculture or horticulture. Reuse may still be possible for purposes such as mine site rehabilitation, highway landscaping or for landfill cover. Sludge which has been conditioned for reuse is also called ‘biosolids’

Conversion of sludge, which is heavily contaminated by heavy metals or toxic chemicals, to oil is technically feasible (Enersludge process). A full scale plant is operating in Perth, Western Australia (Bridle et al., 2000). The conversion is by a pyrolysis process, heating dried sludge to a high temperature in the absence of oxygen or with a controlled amount of oxygen. Capital and running costs of an oil from sludge process are high.

5.7 Sludge disposal

Final or ultimate disposal of sludge, which cannot be reused, is by landfilling or incineration. Since sludge for landfilling usually contains heavy metals or toxic chemicals, lining of the landfill with clay or plastic liner may be required to prevent contamination of groundwater. Incineration of sludge is by a multiple hearth furnace or fluidised bed furnace. Energy input is required to dry the sludge before combustion is self-sustaining. Combustion flue gases usually need treatment to meet air pollution control standards. Investment and operating costs are high.

6. Wastewater and stormwater reuse (Topic d)

Human excreta and wastewater contains useful materials. These are water, organic carbon and nutrients. They should be regarded as a resource. In their natural cycles they are broken down by micro-organisms and become useful to plants and animals (Section 2 (2.2)), thus sustaining natural ecosystems. When improperly disposed these substances can cause pollution, because the organic materials exert oxygen demand, and the nutrients promote algal growth in lakes, rivers and near-shore marine environments.

Human excreta and wastewater contain pathogens. Reuse of the wastes must ensure that public health is maintained. Planned reuse is the key to wastewater reuse. Planning for reuse ensures that public health and protection of the environment are taken into account. Reuse of treated wastewater for irrigation of crops, for example, will need to meet (i) standards for indicator pathogens, and (ii) plant requirement for water, nitrogen and phosphorus. Standards for reuse of wastewater for various purposes have been developed by WHO and many states (see Regional Overviews). Plant requirements for water and nutrients is plant-specific and site-specific (dependent on soil type and climate) and information on these requirements need to be obtained from local sources of information.

Unplanned or unintentional wastewater reuse is already taking place widely when we have human settlements along a major river (e.g. the Mississippi River). Water is withdrawn from the river by a community, treated for water supply and distributed. After its use the water is collected, treated and discharged to the river. This process is repeated many times along the river. The only documented 'intended reuse' of this nature is in Windhoek, Namibia where treated wastewater is returned to the water reservoir supplying water to the town. This was initiated during a severe drought (See Regional Overview for Africa).

While reuse of wastewater for public water supply of drinking water quality standard is the exception, the technology exists to process wastewater to drinking water. A pilot plant at Denver demonstrated that 1 million US gallons per day (3.78 million L/day) of secondary effluent could be treated to produce water that is better in quality than water supplied to the city of Denver.

All water used for drinking purposes has in a sense been used, because in the water cycle (Section 2 (2.2)) water is continuously cycled.

6.1 Wastewater reuse from off-site treatment plants

6.1.1 Wastewater reuse for agriculture

Treated wastewater from off-site treatment plants can be reused for irrigation of parks and gardens, agriculture and horticulture, tree plantation and aquaculture, if these exist or can be established not far from the wastewater treatment plants. For these purposes the wastewater should generally be treated to secondary wastewater standard (< 20 mg/L BOD and < 30 mg/L SS). Total coliforms should be < 1000 organisms per 100 mL for irrigation by spraying. When sub-surface irrigation is used this requirement may not be necessary. A period of non-entry to irrigated sites may need to be observed, particularly for wastewater-irrigated parks and gardens. Irrigation of vegetables for direct human consumption requires a much stricter guideline.

Because requirement of wastewater for plant growth is governed by climatic conditions, soil and plant type, there may be a need for storage of the wastewater. An alternative to storage, if land area is not available for this purpose, is to dispose of wastewater that is excess to requirement. A combination of wastewater for irrigation and aquaculture (see below) is also an option that can be considered.

Land application for treatment of wastewater described in Section 2 (4.2.4) (Slow rate land application and grass filtration) when combined with growing of grasses for grazing by sheep or cattle plus the “cut and carry” system can properly be considered as treatment and reuse of wastewater.

6.1.2 Wastewater reuse for aquaculture

Wastewater reuse for aquaculture has been practised in many countries for a considerable period of time. It has the potential of wider application in the tropics. A special section in this Source Book is devoted to this important topic. This is placed at the end of Section 2 (6). A case study is also presented in the Regional Overview for Central & South America.

6.1.3 Wastewater reuse for industry

Treated wastewater can also be used for industrial purposes, if suitable industries are not far from the treatment plant. Industry’s requirement for water quality ranges widely, from very pure water for boilers of electricity generation to lower water quality for cooling towers. Treated wastewater can fulfil the lower range of this requirement, e.g. water for cooling towers. Secondary-treated wastewater after chlorination may be adequate for this purpose.

With off-site treatment plants reuse of wastewater may be limited by the need to pipe treated wastewater to where it is needed. To implement wastewater reuse in houses for toilet flushing, watering of gardens and other purposes which do not need drinking quality water, a third pipe-reticulation system is required, that is in addition to the reticulation to provide drinking water and the sewer to collect the wastewater. Care is also needed to prevent cross-connection between drinking water and treated wastewater.

'Sewer mining' is the term given to the withdrawal of wastewater from a sewer for reuse near to the point of withdrawal. This provides an opportunity for reuse without having to pipe treated wastewater from the centralised treatment plant. Wastewater needs to be treated to the standard required for the reuse, and may duplicate the function of the centralised treatment plant.

6.2 Reuse of wastewater from on-site systems

Many options are open to a householder who wishes to reuse wastes on-site. One option is separation of all wastes. Urine can be separately collected and stored for later use as a liquid fertiliser, rich in nitrogen, phosphorus and potassium. Toilet wastes can be composted and used as a soil conditioner, rich in organic carbon, nitrogen and phosphorus. Greywater can be treated in a constructed wetland and used for sub-surface irrigation of the garden beds (Figure 2.44). This option may be suitable for a householder who is interested in managing wastes for beneficial uses in the garden, being a keen gardener. Sufficient garden area needs to be available for this purpose.

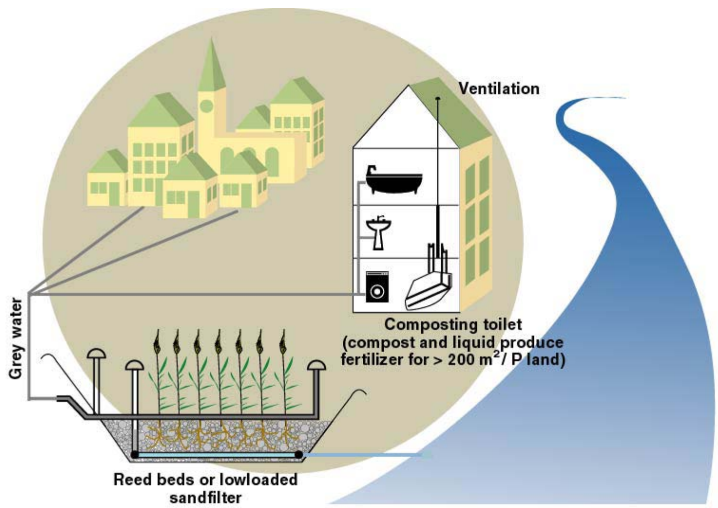


Figure 2.44: Separation of household wastewater for on-site reuse (Lange and Otterpohl, 1997)

Another option is the use of an evapotranspiration system for growing shrubs and trees (see Section 2 (4.1.4)). This is a passive system, not requiring household attention on a regular basis, except desludging of the septic tank every 3 to 5 years. There is a fairly wide choice of shrubs and trees to choose from depending on local soil and climatic conditions.

6.3 Stormwater reuse

Stormwater is generally of a higher water quality than wastewater. Reuse (or strictly 'use') of stormwater can take place at two levels (household and municipal) or even at a larger (regional) scale if desired. Use at the household and municipal levels is described below.

6.3.1 Household level

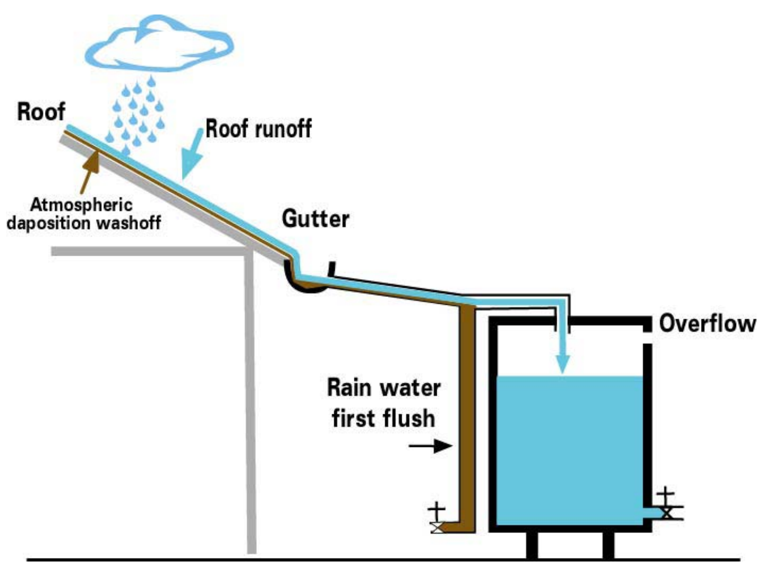


Figure 2.45: Diverter for the first flush from roof run-off

Householders can use stormwater by collecting roof run-off in a tank for use as drinking water (common in arid regions), flushing toilets or for irrigation of the garden. The first flush of roof run-off can be contaminated by dust particles, leaf litter and animal droppings. The first flush can be simply diverted using a simple diverter (Figure 2.45). A screen can be placed at the inlet to the tank to filter gross particles. Water for drinking will still need to be boiled to denature pathogens.

Water from the roof can be directed to the garden beds directly rather than through soakways, and in this way shallow rooted vegetation can benefit from the water, especially in arid regions.

6.3.2 Municipal level

At the municipal level stormwater can be stored in ponds for use for irrigation of parks and gardens and for fire-fighting purposes. This is in addition to employing the ponds for flood control and for improving the amenity value of the water as described in Section 2 (4.3). Other uses are for groundwater recharge, either as a means of storing water, e.g. during the rainy season, for withdrawal in the dry season. Groundwater recharge can also be used to prevent encroachment of sea water near the coast where there is heavy groundwater withdrawal in excess of natural replenishment by precipitation.

Stormwater collected from community buildings (i.e. government and churches) may be stored in reservoirs to be used by the community during dry periods. This method is used in the Pacific SIDS atoll countries of Tuvalu and Kiribati.

7. Wastewater and stormwater disposal (Topic e)

Disposal of wastewater and stormwater should preferably be considered only when reuse options are not feasible. Ultimate disposal of wastewater is either onto land or water (river, lake, ocean).

7.1 Land-based disposal of wastewater

Disposal onto land takes the form of effluent from on-site and off-site treatment systems being allowed to percolate through the ground. For a septic tank, for example, this occurs through the soakage of overflow from the septic tank in a leach drain (Section 2 (4.1.4)). Disposal onto land generally pollutes groundwater, and may reach surface water when groundwater eventually discharges into surface water. The impact of BOD and nutrients in the wastewater on the surface water has been attenuated by soil processes and is therefore not as severe as direct disposal into surface water. Disposal from an off-site treatment plant for groundwater recharge to control encroachment of sea water in coastal areas is a form of reuse.

Injection of wastewater into a deep confined aquifer via a borehole is a possibility. Only treated wastewater with very low content of suspended and colloidal solids can be injected into a deep aquifer to prevent blockage of the pore spaces surrounding the borehole. The long-term effect of deep well injection is still unclear and the method is not generally recommended.

In New Zealand the use of treated wastewater is considered to be a disposal method as opposed to a reuse method. This keeps wastewater from being discharged into bodies of water (rives, streams, groundwater and the ocean). Nutrients (nitrogen and phosphorus) are taken up by the crop thus protecting the groundwater. This system has many advantages as follows:

- Nutrients act as a fertiliser thus reducing amounts from traditional types of fertilisers
- Reduces surface water and groundwater pollution potential
- Culturally exceptional to indigenous NZ people
- More likely to get approval by regulating bodies
- Environmentally better.

7.2 Wastewater disposal to water environments

Disposal into a lake, stream or ocean needs to take into account the ability of the receiving water to assimilate wastewater. The natural purification capacity of the environment is limited (Section 2 (2.2)). Even when wastewater is disposed to the ocean, the area surrounding the outfall can be sufficiently polluted and the pollutants (including pathogens) can be washed towards the beaches. The minimum water quality standard for disposal to a water environment is BOD < 20 mg/L and SS < 30 mg/L. This standard is generally achieved by secondary treatment processes (lagooning or activated sludge treatment). This standard was initially developed for wastewater discharge into rivers, assuming that an eight fold dilution by river water takes place. A class 1 river therefore can maintain a BOD of less than < 3 mg/L (Section 1). Such dilution is not always achieved in arid or semi arid areas.

Nutrients (nitrogen and phosphorus) promote the growth of algae in the receiving water. In lakes and sensitive water environments the removal of nutrients may be required. Furthermore if the wastewater contains high levels of heavy metals and toxic chemicals, these may have to be removed before wastewater disposal. Over the years the requirement for disposal into water environments have become stricter as the impact of pollutants is better appreciated. It can be expected that this trend towards more stringent discharge requirements will continue (See Western Europe and North America Regional Overviews).

7.3 Stormwater disposal

Ultimate disposal for stormwater is onto land (by infiltration to groundwater) and to water environments (river, lake, ocean). These have been covered as part of stormwater treatment (4.3) and reuse (6.3), because they utilise infiltration as a general technique. Techniques for reuse are those that delay its ultimate flow to water environments to improve flow management and hence reduce the frequency and extent of flooding. At the same time these techniques also generally remove pollutants (particulates and oils) prior to the water reaching a river, lake or the sea, while creating amenities such as wetlands, waterfowl habitats and water-based passive and active recreational facilities.

8. Sound Practices

8.1 Technology choice

Environmentally sound practices in wastewater and stormwater management are practices that ensure that public health and environmental quality are protected. A range of technologies exist that can achieve this objective (Section 2 (2) to (7)). A summary is shown in Table 2.5. Even though this table does not cover all available technologies, they represent major technologies for situations that are likely to be encountered. The Regional Overviews include technologies that are modifications or variations of the listed technologies or represent practices or advances in the regions.

Common to all sound technologies is that there is a scientific basis for the physical, chemical and biological processes for the removal of pathogens and pollutants from the water. These processes are largely akin to the purification and recycling processes taking place in nature (Section 2 (2.2)). Properly designed, constructed, maintained and operated these technologies can achieve protection of public health and the environment, and can recycle water and nutrients, which are beneficial to sustaining ecosystems and life.

Associated with each technology hardware is a philosophical basis or approach, e.g. separation of waste components (dry conservancy), or conveying all wastes away with water (water based conveyance) minimising capital cost, minimising maintenance requirement; or maximising reuse maintenance and operational requirements, which are the software associated with the technological hardware, and therefore level of skills required to operate the hardware and software, and consequently training requirements for personnel.

The choice of technology is determined by environmental, economic and social factors.

8.2 Environmental considerations

Achievement of protection of environmental quality is implicitly assumed when we consider technologies for wastewater and stormwater management. These considerations are (i) the need to protect the environment and (ii) the imperative of recycling/reusing the water and nutrients in the water. The first factor is usually taken into account by making sure that standards for discharge of wastewater are met. Standards alone should not be relied upon, because it is the capacity of the environment to assimilate the wastes that should not be exceeded. Each local environment has its own capacity depending amongst others on the natural throughflow of water, climatic, vegetation and soil conditions.

Reuse of the water and nutrients conserve these resources in a world where water will in the future be a precious resource for growing food and maintain ecosystems for the world's increasing population and standard of living. Reuse of water can in fact fulfil the objective of protecting the environment, because reuse has standards which have to be met prior to the water being able to be reused. A corollary to the above two factors is the need to exclude toxic and hazardous chemicals from being mixed and discharged with human excreta. Treatment, reuse or disposal of wastewater and stormwater containing toxic and hazardous chemicals will be considerably more difficult than treating the toxic and hazardous wastes separately.

Table 2.5: Technologies for wastewater and stormwater management (with relative costs, environmental impact and maintenance requirement)

Wastewater management technologies

Technology	Capital cost	Operation & maintenance cost	Environmental impact
On-site technology			
Pit latrine	Low	Low	Pollution of groundwater
Composting toilet	Low	Low	Reuse of nutrients
Pour flush toilet	Low	Low	Pollution of groundwater
Improved on site treatment unit	Medium to high	Low to medium	Reuse of water and nutrients
Off-site technology			
Collection technology			
Conventional sewerage	High	High	Dependent on treatment
Simplified sewerage	Medium to high	Medium	Dependent on treatment
Settled sewerage	Medium	Low	Dependent on treatment
Treatment technology			
Activated sludge	High	High	Nutrients may need removal
Trickling filtration	Medium	Medium	Nutrients may need removal
Lagoons	Low to medium (dependent on cost of land)	Low	Nutrients may need removal; aquaculture can be incorporated
Land-based treatment	Low to medium (dependent on cost of land)	Low to medium	Reuse of water and nutrients
Constructed wetland	Low to medium (dependent on cost of land)	Low	Amenity value
Anaerobic treatment	Medium	Medium	Produces biogas; further aerobic treatment needed

Stormwater management technologies*

Technology	Source control	Site control	Regional control
Filter strips and swales	√		
Filter drains and permeable surfaces	√		
Infiltration devices		√	
Basins and ponds			√

*Cost increases from source control to regional control technology.

Conservation of resources needs to consider water conservation at the point of its use. Less water used means less wastewater produced. The hierarchy of waste management discussed in Section 1 (4) emphasises this point, and should be seriously considered in achieving sound technology practice.

8.3 Economic factors

Sound practices require that costs are optimised. An indication of relative costs of technologies described in this Source Book is provided in table 2.5 and in Appendix 2. Optimising the cost of technology for wastewater management needs to consider (1) availability of land, (2) labour costs, (3) land uses and (4) economy of scale. Land is required for wastewater and stormwater management either underground to lay pipes or on the ground for a treatment plant or for land-based disposal. If low cost land is available a lower cost technology utilising more land can be chosen rather than a higher cost technology using less land area. Lagoons, for example, can be installed rather than an Activated Sludge Treatment Plant, because both can achieve the same standard for final BOD and SS. Labour cost for construction and maintenance is an important consideration. On-site treatment systems are generally more conducive to the use of manual labour for construction and maintenance, whereas off-site treatment systems generally require specialised equipment and skilled labour.

Availability of land, when an on-site system is used, enables reuse of treated wastewater at the site. Similarly when an off-site system is used, nearby agriculture, horticulture, forestry or industrial activities can present an opportunity for reusing the wastewater.

Economy of scale may be taken advantage when total cost of treatment is considered. Individual on-site systems do not present an opportunity for economy of scale for cost reduction, unless they are constructed in standard sizes and prefabricated components are manufactured in large quantities. Off-site treatment of wastewater from many households provides an opportunity for cost-saving in treatment. The cost of treatment per unit volume of wastewater will decrease with an increase in population served. The cost of collection will, however, increase, because larger diameter pipes and additional pumps and pumping stations are required. This will counter the cost saving in centralised treatment. In centralised collection and treatment systems with deep sewerage, the cost of pipes and pumps is generally a substantial proportion of the capital cost (up to 85%). There will be an optimum size of population served by an off-site treatment system when the combined cost of collection and treatment are considered. When opportunities for water reuse are also considered (piping of reuse water, availability of land or opportunities for reuse) there seems to be an optimum to the size of population served (Figure 2.46).

The economics of wastewater management needs to consider the benefits of improvement to public health and long-term affordability of sanitation services to the community. The benefits of improved public health to the economy of a country is difficult to quantify, although estimates have been made on the cost to the economy as a result of people suffering from illnesses from waterborne diseases (Appendix 1). Similarly the economic benefits of the protection of the environment from improper disposal of wastewater and stormwater is difficult to estimate. A case for subsidy to communities to install wastewater treatment facilities has been put forward (The all beneficiaries contribute (abc) principle).

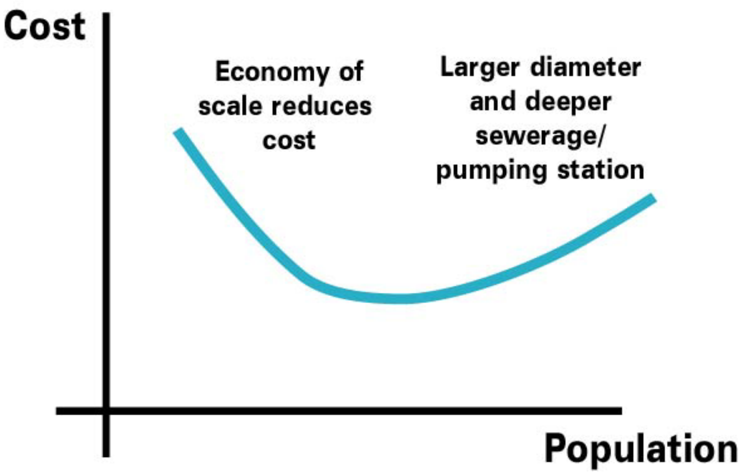


Figure 2.46: Cost of treatment as a function of population served

From a community's point of view the affordability of a wastewater collection and treatment system is an important factor. A percentage of the average person's income in a community, or of the average value of housing appears to be a figure that can be used as a measure of what a community can afford. What the percentage figure should be is determined by the importance given by community members to having the wastewater system in their community. The priority given to wastewater management in turn is dependent on the community having the information that will help them decide on its importance relative to other household and community needs. Hygiene promotion and education is needed to provide this information. An example of an excellent hygiene promotion is a publication by WHO (WSSCC Working Group on Promotion of Sanitation, 1998).

Selection of technology

Procedures to consider economic and environmental factors in a systematic way have been developed. These range from a single decision-making flowsheet to a computer software package.

Figure 2.47 and Figure 2.48 illustrate flowsheets that have been developed for selection of wastewater technology in developing countries in both urban and rural communities. Computerised decision making software is based on the same methodology as illustrated in the flowsheets. Two programs (SANEX and WAWTTAR) are briefly described in the accompanying boxed sections to illustrate their advantages and limitations.

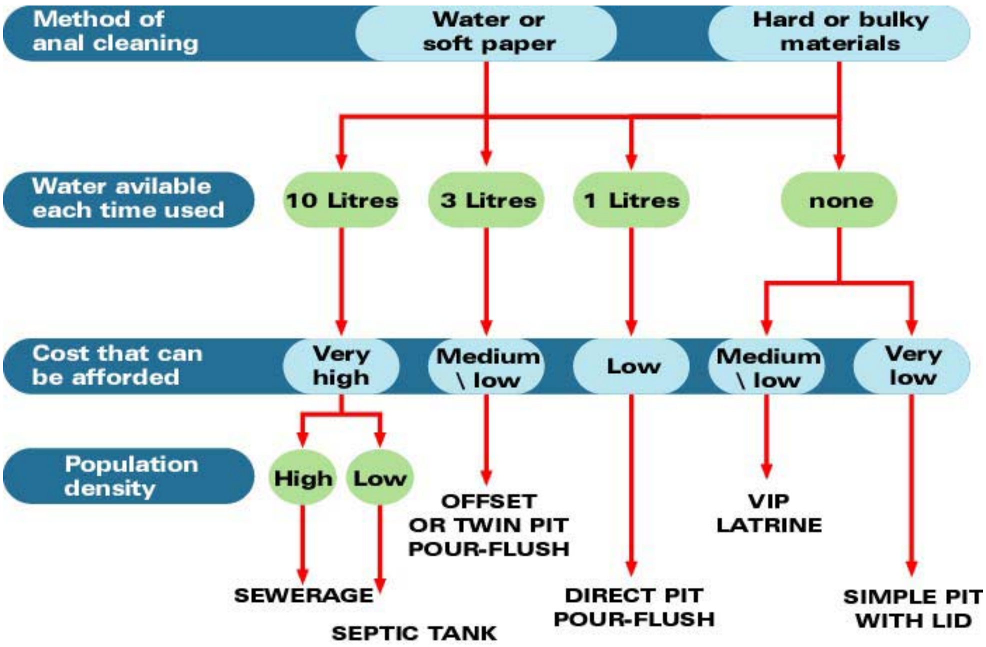
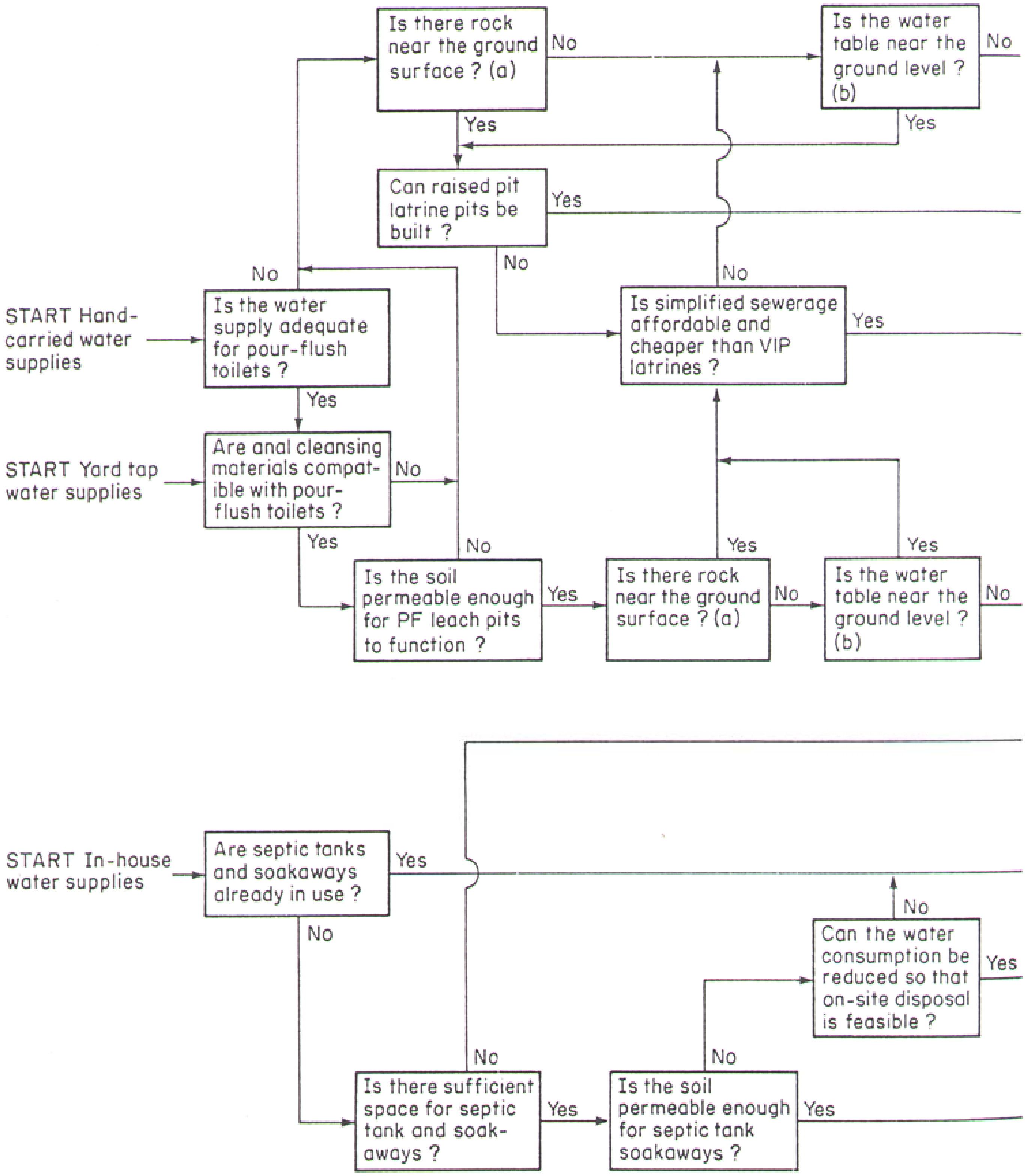


Figure 2.47: Simple decision making flowsheet for choosing wastewater treatment systems (Pickford, 1995)



Sanitation technology selection algorithm. Notes: (a) to < 1 m; (b) to within 0.5 m either or seasonally; (c) decide between single pits and alternating twin pits

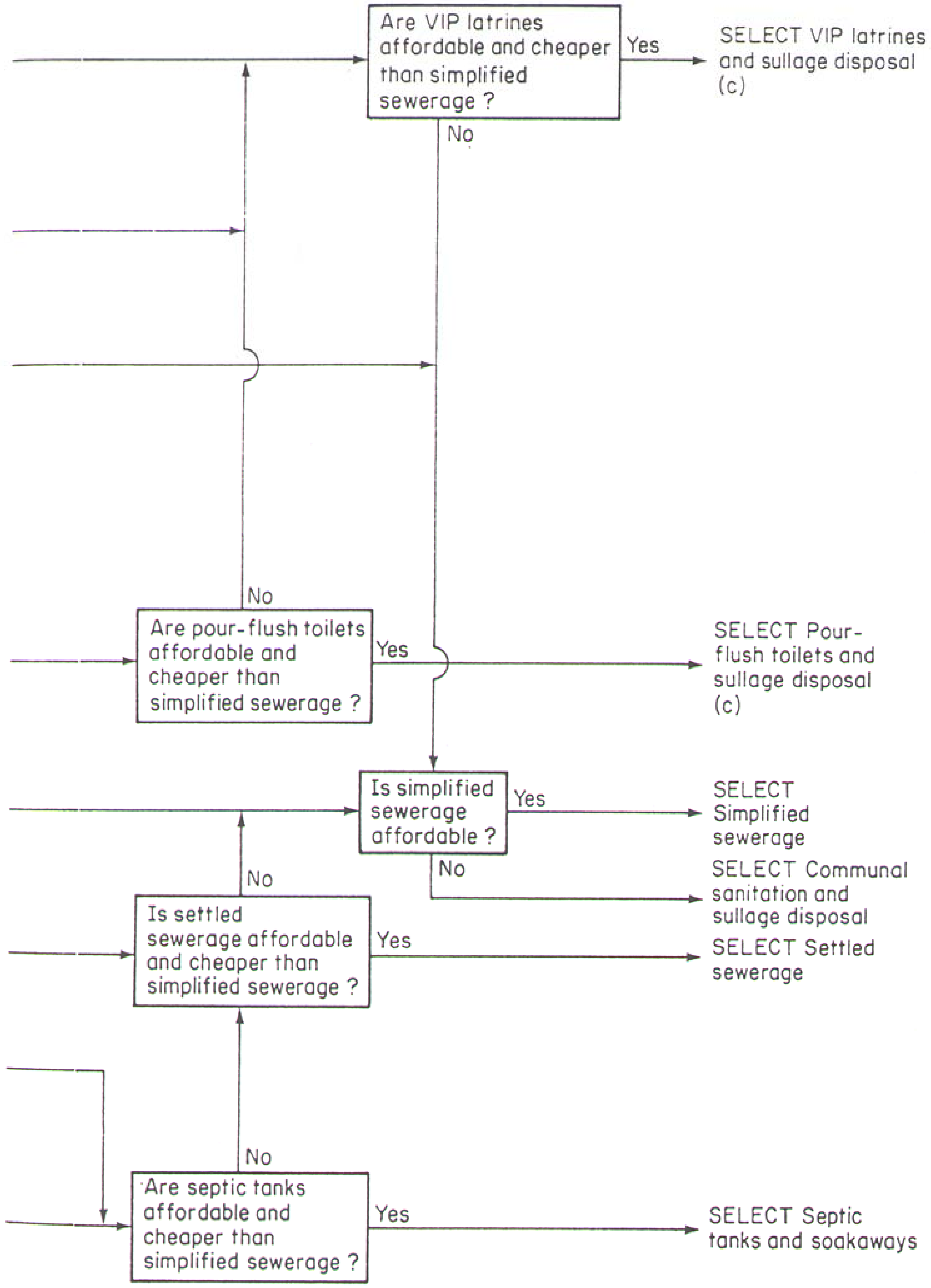


Figure 2.48: Decision making flowsheet for choosing wastewater treatment technologies (Mara, 1996)

Computer software of SANEX: Description of procedure and capability

The purpose of this computer program is to support decision makers and project beneficiaries in identifying feasible alternatives and in evaluating the adequacy of these alternatives with respect to community circumstances. The three questions which the program attempts to answer are:

1. Which sanitation technologies are relevant to rural and urban communities in developing countries?
2. Which are the relevant criteria to evaluate the appropriateness of these technologies?
3. How can these criteria be incorporated into a decision aid that can be applied by decision makers to concrete projects?

Methodology

Two-Stage Evaluation

This model features two distinct evaluation stages (Figure 1). During the screening stage, infeasible alternatives are eliminated based on mainly technical criteria. Subsequently, during the comparative stage, the remaining alternatives are compared with regard to the indicators implementability and sustainability. Apart from technical issues, this stage considers numerous sociocultural objectives. Implementability expresses the probability that sanitation facilities can be constructed within the period and with the financial resources usually required in favourable conditions. Sustainability expresses the probability that facilities serve beneficiaries according to their design throughout their design life.

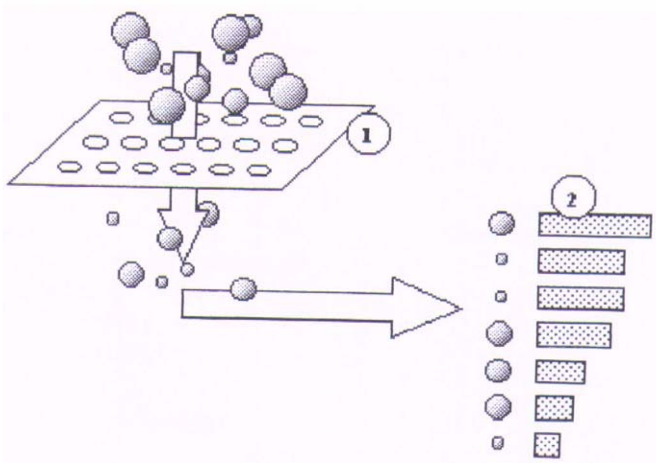


Figure 1: Screening evaluation is symbolised by the screen (1) which lets only technically feasible options (represented by the smaller spheres) pass. Comparative evaluation is symbolised by the horizontal bar graph (2), indicating performance for each feasible option.

Multi-Level Amalgamation

A major obstacle to formulation the comparative component of the algorithm was the amalgamation of numerous criteria outcomes. The application of conventional methods, such as the arithmetic mean, would have resulted in a diminishing effect of the individual criterion. In order to preserve the effect of criteria, a new method for amalgamating criteria on multiple levels was developed, which would also allow the simultaneous application of various methods like the arithmetic and the geometric mean. The combined advantages of multi-level amalgamation are reflected in more plausible evaluation results.

Costing of Sanitation Alternatives

Assuming the planners in developing countries usually have sufficient access to financial expertise, no criteria to assess the affordability of sanitation systems were formulated. Instead, it was decided to develop a costing model that would enable the proposed decision aid to estimate the capital as well as the recurrent costs of all alternatives. Further, a simple method based on the local residential building cost was developed to convert these estimates to costs in local currency units, as they would occur in the project area.

Validation

The above work resulted in an evaluation model for assessing the implementability, the sustainability and for costing sanitation alternatives in developing countries. In 1998, in order to validate this model, a second journey was undertaken to Southeast Asia and to Europe. Based on the application to nine case studies, several modifications emerged to be necessary. The main results are explained in the following section.

Outcome

The expert system software SANEX© was developed for the MS Windows operating environment. The knowledge base of this software contains more than 80 sanitation alternatives, which are combinations of the technologies outlined in the table below, and uses around 50 technical, sociocultural and financial criteria for their assessment. The costing component employs approximately 50 functions.

Sanitation alternatives considered in SANEX

Toilet facilities: • Pour-flush toilet • Cistern-flush toilet *On-site facilities:* • Simple pit latrine • VIP latrine • Pour-flush latrine • Aquaprivy • Septic tank • Vault (vacuum cartage) • Seepage pit • Drain field *Public facilities:* • Public toilet block • Overhung latrine	*Resource recovery:* • Double-vault composting toilet • Excreta-fed fish pond • Septic tank for excreta reuse • On-site biogas digester *Sewerage:* • Covered stormwater drains • Conventional sewerage • Simplified sewerage • Settled sewerage *Off-site treatment:* • Communal septic tank • Imhoff tank • Primary treatment • Waste stabilisation ponds • Activated sludge treatment

Reference: Loetscher (1998)

Computer software of WAWTTAR: Description of procedure and capability

The WAWTTAR program was designed to assist financiers, engineers, planners and decision-makers in improving their strategies toward sustainable water and sanitation coverage while minimizing impacts on water resources. It was developed specifically for application at the pre-feasibility stage of project development to assist planners select suitable water and wastewater treatment processes which are appropriate to the material and manpower resources available in their particular location at particular times. The program is designed to assist decision-makers dealing with the following types of issues:

1. Identification of the least-cost treatment scheme for a community with site-specific socio-economic and geographical conditions;
2. Presentation of risks to long-term sustainability of selection of identified treatment schemes;
3. Collection of viable combinations of technologies available to a specific community to meet water reuse standards or guidelines;
4. Identification of least-cost wastewater collection and treatment options for high-density, peri-urban communities;
5. Balancing of coverage and risk for selection of treatment schemes within financial constraints;
6. Selection of technologies to meet particular water quality and/or reclamation standards; and
7. Sensitization of decision-makers to the issues of sustainability related to water, sanitation, wastewater and/or water reuse.

Technology Selection

The main use of WAWTTAR is as a tool for individuals with a technical background to screen and investigate possible water and wastewater treatment options. It enables the user to accomplish this by examining the public health status, water resource requirements, material availability, cost structures and ecological conditions which exist in a particular community. The program assesses these combined factors to generate a set of comparable and refinable feasible technical solutions.

WAWTTAR incorporates innovative and alternative technologies and emphasizes water reuse as an integral component of treatment schemes. WAWTTAR does not, however, exclude conventional options and is of equal usefulness in the screening and examination of such options as well. The main application of WAWTTAR is in technology assessment and evaluation for urban population centers with significant human, material and financial resources available for infrastructure improvement. In most of these urban centers, access to adequate sanitation is typically available for most residents through sewers or individual septic tanks.

For many others, especially those living in peri-urban zones, residents are typically without acceptable wastewater collection and treatment systems. What systems do exist in these communities generally follow conventional designs although alternative systems may be applicable. WAWTTAR has also been designed to account for the particular, non-conventional wastewater collection and treatment systems which are applicable to these types of settings.

Operation of WAWTTAR

WAWTTAR requires an IBM-PC compatible computer running Microsoft Windows 95 or later. In the basic operation of WAWTTAR, fundamental parameters such as performance standards, material costs, raw water or wastewater quality, community needs and capabilities, and planning horizons are entered by the user into easily editable data fields. The user then constructs several possible sequential treatment schemes from a comprehensive list of available treatment processes contained in the software program. WAWTTAR first screens these options according to the needs, capabilities and resources of the community in question, and it discards those options which are infeasible. WAWTTAR then calculates the performance, construction costs and operations and maintenance costs of the remaining viable treatment schemes. Feasible options can then be compared based on performance and annualized costs.

Data Collection

WAWTTAR presents numerous tables in which the user is required to supply information. These tables serve not only as inputs to the software, but also as guides for planners and decision-makers regarding the range and quality of information which should be considered in the development of infrastructure initiatives.

Community Data

The principal set of data which the user must individually input are those which are site-specific to the location being considered for infrastructure improvement. These community data are divided into several categories as displayed below:

1. **General**
   - Community identification
   - Community location
   - Stakeholders
2. **Demographic**
   - Population, density and growth rate
   - Household size
   - Spatial growth
   - Current and projected water use
   - Current and projected wastewater production
3. **Resources**
   - Availability of construction, operation and maintenance equipment and materials
   - Energy and labour resources
   - Availability of chemicals, media and laboratory services
4. **Hydro-meteorological**
   - Precipitation and evaporations rates
   - Surface temperatures and frost lines
   - Raw water and wastewater quality
   - Point source inputs
   - Collection system description
5. **Financial**
   - Planning horizons
   - Exchange rates
   - Interest, discount and inflation rates
   - Construction and O&M cost indices
   - Land values
6. **On-site**
   - Soil and ground types
   - Depth to water table
   - Isolation distances from relevant features
   - Dwelling types
   - Defecation practices
   - Gender issues
   - Accessibility and waste hauling practices

Treatment Process Data

The second type of data utilized by WAWTTAR is Treatment Process Data. Such information for nearly 200 water and wastewater treatment processes is provided in the WAWTTAR database. For each process, a set of tables contains information that defines the characteristics of the process. The tables and their content are shown below:

1. General
- Type of process
- Identification of descriptive files for process

2. Construction
- Equipment, energy, labour and material requirements
- Construction costs relative to hydraulic, solids and organic loadings
- Economic life span of process

3. Operation and Maintenance
- Land requirements relative to hydraulic, solids and organic loadings
- Equipment, chemical, media, laboratory and material requirements
- Process control and energy needs
- Operation and Maintenance costs relative to hydraulic, solids and organic loadings
- Solids production rate and moisture content
- Allowable influent quality values
- Removal efficiency for influent constituents
- Adaptability of process to upgrading, flow variations and influent quality

4. Siting
- Allowable precipitation and surface temperatures
- Required surface soil types and percolation rates
- Necessary horizontal and vertical isolation distances

5. Impacts
- Nutrient management
- Pathogenic organism production
- Pest breeding
- Odour generation
- Requirements for education

6. On-site Miscellaneous
- Institutional requirements
- Allowable population density and dwelling requirements
- Adaptability to social practices and living conditions
- Waste handling requirements

Each process is defined by up to three generic construction cost, O&M cost and land requirement curves based on hydraulic loading, organic loading and solids loading.

Building Treatment Trains

As has been previously noted, it is a requirement that users of WAWTTAR have at the very least an acquaintance with water and wastewater treatment processes. This knowledge is first applied to WAWTTAR in the selection of the sequence of processes which the user instructs WAWTTAR to consider. The user must select processes and arrange them in a logical order in terms of the flow of the water, wastewater and/or solids.

The development of a wide range of alternative treatment trains for consideration is at the heart of the WAWTTAR program. The user is able to prepare large numbers of different treatment trains by combining the various unit processes found in the WAWTTAR process database. The number and types of alternatives to be considered is a decision the user must make early in his or her planning process. The wider the variety and the greater the number of treatment train alternatives proposed, the greater the probability that a sustainable, feasible solution will be found.

Results

After WAWTTAR has completed the calculations resulting from the combination of site-specific community information and the selected treatment trains, the program output is written into two output files. These files are the Feasible Solution File and the Infeasible Solution File. A display menu is used to view these files along with other output files.

Reference: Finney and Gearheart (1998)

Decision making processes for stormwater management have also been developed (see Regional Overview for West Europe, section 6.2.2). To achieve long term sustainability goals the concept depicted in Figure 2.49 can be followed. Managers, Developers, Regulators, Designers and Environmentalists all need to be involved in the decision making process. Technology choice should include technical as well as 'cross-cutting' issues (Section 1.3).

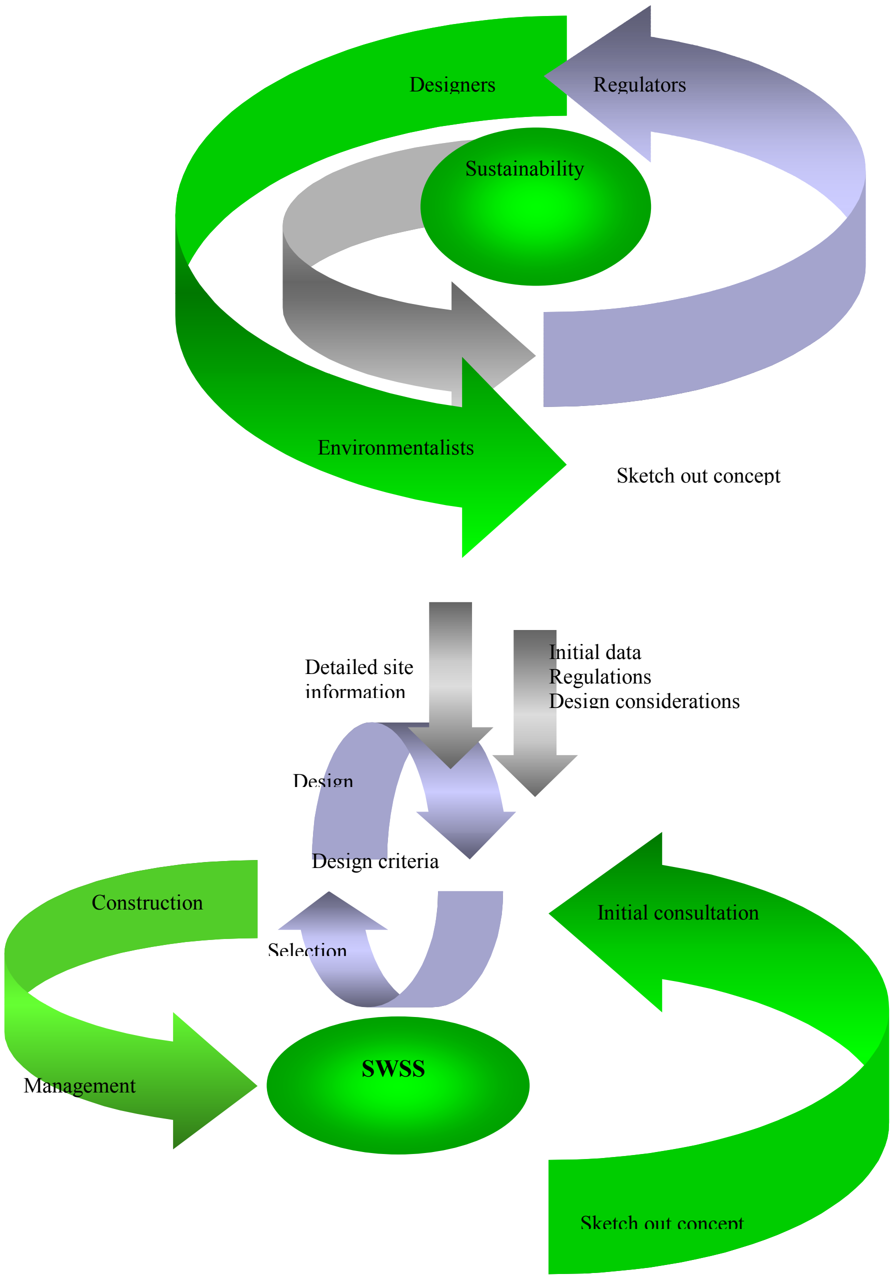


Figure 2.49: Decision making process to achieve sustainability
(SWSS = sustainable wastewater and stormwater systems)

Small islands have their particular circumstances, and technology choice. These are considered in the Regional Overview for Small Islands Developing States Pacific and Caribbean (3(8) and 3 (9)). A useful publication is Sanitation for Small Islands – Guidelines for Selection and Development (Depledge, 1997).

8.4 Social and institutional factors

Social and institutional factors are most important in the delivery of any service including wastewater and stormwater services. These factors include the processes adopted by a community, region or country to plan, finance and implement the provision of sanitation services. Each community has developed their processes, and these may have been developed over a long period. The importance of involving the community in decision making to introduce wastewater and stormwater management has been reiterated as being important to ensure long term sustainability of the system.

Difficulty can be encountered with new communities developing in the fringes of large cities, where there may not have been the tradition of community decision making. The involvement of a community-based or non-government organisation may assist. Financing and cost recovery are important considerations for these communities, which generally are resource poor.

The management of ablution facilities illustrates the importance of ownership or sense of ownership. A private ablution facility is generally better maintained than a communal ablution facility. Hygiene maintenance of a private facility is usually the responsibility of a person in the household. This is usually the housewife, who cleans the facility or arranges its regular cleaning and also ensures that members of the household play their part. A communal hygiene facility can suffer from a lack of unclear responsibility for cleaning the facility or from abuse by irresponsible members of the community.

Requiring payment for use of a communal or public ablution facility, with an attendant for collection of payment and responsible for cleaning, appears to be a good model (Sulabh, India).

Sulabh International Social Service Organisation

Salabh Shauchalaya Complex is a system of operating and maintaining community toilets with bathing, laundry and urinal facilities with attendant's service round the clock. It is a pay-and-use system with people's participation without any burden on public exchequer or local authorities. Sulabh complexes have been welcomed both by the people and the authorities due to their cleanliness and good management.

These complexes have electricity and 24 hours water supply and soap powder is supplied free to users for washing hands. The complexes have separate enclosures for men and women. The users are charged nominal sum for using Shauchalayas and baths.

(www.sulabhinternational.org)

There is an emerging trend for governments to privatise provision of wastewater and stormwater services. The private sector has developed considerable expertise in providing wastewater and stormwater services. These services range from developing master plans, community consultation, design, construction, operation & maintenance of collection, treatment and disposal facilities, to training of personnel. It is not clear whether the private sector achieves greater management efficiency when compared to a well operated government agency. The latter may not, however, operate in a particular locality, and capacity building within the government sector is required. Government's responsibility remains in providing policy direction, providing overall planning framework, and ensuring that public health and environmental objectives are achieved. Governments should use the private sector expertise to supplement specialist waste disposal areas while still keeping control. Hygiene promotion should remain a high priority for governments, irrespective of public or private provision of services.

Communities with low incomes/resources require special attention with respect to achieving the wider public health and environmental objectives. The case of providing funding for wastewater and stormwater services is compelling from the overall public health and environmental benefits outside these communities.

8.5 Scenarios for Sound Practices

General scenarios can be sketched based on population density to illustrate integration of technology, environmental, economic and social factors. For a low population density and where land is available around dwellings, on-site systems with on-site reuse provide householders with options which are a function of water availability, toilet type and desired reuse of blackwater and greywater. Use of a double vault composting toilet (2 (4.1.2)) and greywater for subsurface irrigation is shown in Figure 2.50. Maintenance requirement will be emptying the vault (say, every 6 months), windrow-composting the content with garden waste and diverting blackwater from a full vault to the one just emptied. Irrigation system for greywater need to be checked weekly.

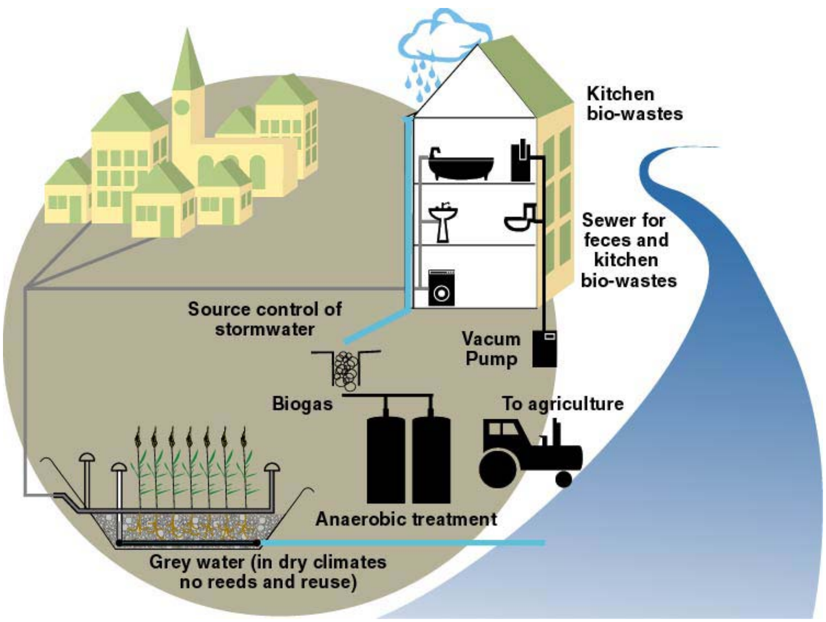


Figure 2.50: Composting toilet for blackwater and sub-surface irrigation of greywater (Lange and Otterpohl, 1997)

A system requiring less householder maintenance is a septic tank with an inverted leach drain or evapotranspiration trench (2 (4.1.5)). The septic tank needs to be de-sludged every 3 to 5 years. This is done by calling a sludge contractor. This service should be available in the community for this option to operate satisfactorily including the safe disposal of the sledge by the contractor.

For a high population density, community ablutions blocks with payment for use can work well. The wastewater can be conveyed to a location where land is available for land-based treatment (2 (4.2.4)) and reuse through grazing grasses irrigated by treated wastewater. The operator of the ablutions facilities needs to ensure public health requirements for the wastewater reuse are met.

Toilet facilities in individual dwellings are an option with wastewater collected using simplified sewerage (2 (3.2)). This can be condominial sewers or with street connections depending on community choice. Collected wastewater is treated using a series of lagoons (2 (4.2.3.)), with the final lagoon employed for aquaculture (2 (6.1.2.)). Depending on land use downstream of the lagoons, wastewater can be reused further for agriculture, horticulture or tree plantation.

The requirement of planning a sewerage system within a catchment basin (to use gravity flow), the environmental requirement for reuse of wastewater nutrients (to prevent pollution), the economic requirement of balancing economy of scale of treatment and the cost of the sewer pipes, and the social requirement for community consultation point to planning for a community-scale collection, treatment and reuse of wastewater. The optimum size of the population served for a community-scale systems will depend on local conditions, which in turn are determined by local geographical (topography, climate, soil), environmental, economic and social/institutional considerations.

9. Wastewater reuse through aquaculture

9.1 Aquaculture

9.1.1 Introduction

Wastewater-fed aquaculture has a long history in several countries in East, South and Southeast Asia (Edwards and Pullin, 1990; Edwards, 1992). It provides food, employment and income for millions of people. Research over the past three decades has provided a scientific understanding of how these systems function. International organizations, including the World Health Organization, recommend that wastewater reuse should always be considered as an option in schemes to improve sanitation in developing countries (WHO, 1989). In reality, relatively few wastewater-fed aquaculture systems have been implemented recently. In most areas where wastewater-fed aquaculture currently exists, the practice is threatened or in decline for diverse reasons.

Key questions that need to be addressed concerning the future role of wastewater-fed aquaculture as a sustainable technology are:
- what constitutes sound practice technically, including a consideration of public health?
- in what social and economic contexts is wastewater-fed aquaculture an appropriate technological option ?

To attempt to answer these questions the following are presented:
- a brief outline of current wastewater reuse systems and their relation to sanitation
- a discussion of how wastewater-fed systems work
- an overview of major constraints facing wastewater-fed aquaculture
- a schema of the possible evolutionary development of wastewater-fed aquaculture as societies pass through successive stages of development
- an outline of sound wastewater reuse practice with discussions of public health, culture systems and opportunities for wastewater-fed aquaculture.

Case studies are presented of two large fish culture systems fed with conventional sewage, in Vietnam, Case Study 1 (Vo, 1996) and India, Case Study 2 (Ghosh, 1990). Besides traditional practice, the Indian case study includes an outline of a recently introduced, improved system incorporating pretreatment of wastewater (Ghosh, 1995, 1998). A third case study from Bangladesh describes wastewater treatment and reuse with duckweed, a high-protein feed for fish. Systems involving conventional wastewater and nightsoil are outlined.

9.1.2 Current wastewater-reuse practice

The term “wastewater” is used generically to cover the range of forms in which human excreta is reused in aquaculture, rather than restricting it to water-borne excreta or sewage. There is great diversity of systems involving cultivation of animals, (mainly fish) (Photo 1) and plants (mainly aquatic vegetables such as water spinach) (Photo 2) (Table 2.6).

Most reuse systems have been developed by farmers and local communities rather than by scientists and engineers; the primary motivating factor has been reuse of nutrients for food production rather than wastewater treatment, and with scant attention to either waste treatment or to public health.

Photo 1: Fish cultured in wastewater-fed East Lake, Wuhan, China

Photo 2: Harvesting water spinach cultivated in sewage in Vietnam.

Fresh excreta or nightsoil may be used directly through overhung fishpond latrines (Photo 3); and nightsoil and septage may be transported (cartage) by various means to fishponds for use as a fertilizer. Overhung latrines are widespread on fish ponds in China, Indonesia and Vietnam. Duckweed is also cultivated in small ponds fertilized directly with nightsoil from a latrine in Bangladesh and is harvested for feeding to fish in nearby ponds. Cartage of nightsoil (manually on foot or bicycle, by boat, or by vacuum truck), and to a lesser extent septage, for use as a fish pond fertilizer is widespread in China and Vietnam.

Photo 3: An overhung latrine on a fish pond in Vietnam

Table 2.6: Types of wastewater-fed aquaculture systems

Wastewater type and delivery system	Aquaculture system	Cultured organism	Location
Nightsoil, (overhung latrine)	Pond	Fish	China, Indonesia, Vietnam
Nightsoil, (overhung latrine)	Pond	Duckweed	Bangladesh
Nightsoil, septage (cartage)	Pond	Fish	China, Vietnam
Contaminated surface water (Waterborne)	Pond	Fish	Bangladesh, Indonesia, Vietnam
Contaminated surface water (Waterborne)	Pond	Duckweed	China, Taiwan
Contaminated surface water (Waterborne)	Cage in river	Fish	Indonesia
Contaminated surface water (Waterborne)	Stakes in river, shallow pond	Aquatic vegetables	Widespread in Asia
Sewage (water borne)	Pond	Fish	China, Germany, India, Vietnam
Sewage (water borne)	Pond	Duckweed	Bangladesh

Much wastewater-reuse occurs in surface waters that have been faecally contaminated by improper sanitation in developing countries. These provide a ready source of nutrients for aquaculture and agriculture in periurban areas. Contaminated surface waters are used to culture fish in ponds in Indonesia and Vietnam with long standing traditions of aquaculture; and more recently in Bangladesh in low lying pond areas in periurban areas. Cultivation of duckweed in China and Taiwan has a long tradition to provide feed for herbivorous grass carp fingerlings (Photo 4).

Photo 4: Harvesting duckweed cultivated on contaminated surface water to feed fish in Taiwan

Common carp are raised in cages in contaminated rivers in Java; and aquatic vegetable cultivation is widespread in periurban areas of many Asian cities where they are staked in shallow polluted surface waters or cultured in ponds fertilized with the nutrient-rich water.

Aquaculture using conventional waterborne wastewater or sewage is not widespread. Experiments with conventional sewage began in Germany towards the end of the last century, leading to the development of about 90 municipal, wastewater-fed aquaculture systems by the 1950s (Prein, 1996). All have since ceased to operate except the one in Munich, which is now used only for tertiary treatment of activated sludge effluent, a bird sanctuary and a recreation area.

Fertilization of fishponds with conventional sewage in Asia developed initially in Calcutta, India in the first part of this century; in cities in China since the 1950s; and in Hanoi, Vietnam since the 1960s. In all areas it is under threat or in decline, especially in China where the practice is now banned by many local authorities because of contamination of fish with toxic substances from industrial wastewater. A system has recently been introduced into Bangladesh to treat conventional wastewater with duckweed.

9.1.3 How does wastewater-fed aquaculture work?

Wastewater is not reused directly in aquaculture, with the sole exception of the overhung pond latrine system in which fish do consume faeces. In most systems the nutrients contained in the wastewater are used as fertilizer to produce natural food such as plankton for fish. Nutrients, mainly nitrogen and phosphorus, are also taken up directly by large aquatic plants such as duckweed which is cultivated for animal feed, and aquatic vegetables such as water spinach and water mimosa cultivated for human food.

Wastewater nutrients in fish culture stimulate natural food chains leading to production of photoplankton and zooplankton which are filtered by plankton feeding fish such as carps and tilapia. Organic matter fertilization also stimulates the production of benthic organisms such as chironomids (midge larvae) and tubifex worms which provide natural food for benthic fish such as common carp.

As wastewater provides a source of nutrients for aquaculture, it is technically feasible to link it up with most sanitation technologies, providing that land is available at reasonable cost. There is a need to reconcile the differing approaches of sanitary engineers and aquaculturists to wastewater-fed pond design (Table 2.7). The former aim to maximize wastewater treatment whereas the latter aim for maximum fish production. This leads to a discrepancy in organic loading rate of about one order of magnitude to attain these differing objectives. A facultative stabilization pond can be loaded at 200-300 kg BOD_5 /ha/day but for maximum fish production a far lower loading rate of 10-30 kg BOD_5/ha/day is required which requires a much higher relative area of pond for the same amount of wastewater. Unlike wastewater treatment alone, a combined wastewater treatment and reuse system must maintain adequate dissolved oxygen for fish.

The most important criterion that determines the productivity of a fertilized fish pond is the rate of nutrient rather than organic matter loading rate. In practical terms this can be given in terms of kg N rather than kg BOD_5, with an optimal rate of 4 kg N/ha/day. In a wastewater-fed system the biological oxygen demand from the bacterial breakdown or respiration of organic matter added in wastewater is far less important than that of the night-time respiratory demand of phytoplankton which grow as a result of the nutrients contained in the wastewater.

Table 2.7: Differing approaches of sanitary engineers and aquaculturists to wastewater-fed pond design.

	Sanitary Engineer	Aquaculturist
Aim	Maximum wastewater treatment	Maximum fish production
BOD_5 loading rate (kg/ha/d)	200 – 300	10 - 30
Relative pond area	Low	High

Source: Edwards and Pullin (1990a).

Farmers have learned by experience how to culture fish, first in static-water nightsoil-fed ponds and more recently in conventional wastewater-fed fish ponds. They assess water quality by observing water colour; degree of light penetration into the pond water column; and behaviour of the fish. Good water quality contains adequate concentrations of protein-rich phytoplankton for fish to filter for feed; and adequate levels of dissolved oxygen for fish during the night when photosynthesis, the main oxygen providing mechanism in the pond does not operate. Indicators are a medium green colouration of pond water; penetration of light to between 10-20 cm into the water column; and minimal surfacing of fish at dawn to gulp air.

Farmers use various strategies to fertilize fishponds with wastewater to simultaneously produce feed for fish and maintain adequate dissolved oxygen. Relatively small amounts of high strength organic matter such as nightsoil or septage are used intermittently at intervals of a few days to provide nutrients but not overload the pond with organic matter. Sewage or contaminated surface waters are allowed to flow, or are pumped into, fish ponds in regulated amounts to maintain water quality. Wastewater may be used continuously or intermittently depending on need, which is influenced by stage in the culture cycle, relative volumes of pond and wastewater flow, and season with respect to lower winter temperatures in temperate climates and dilution due to monsoon rains in the tropics. In areas where there is only wastewater and no supply of clean fresh water, ponds are filled up with raw wastewater and are left for 2-3 weeks for natural purification to improve the quality of the water before fish are stocked. Wastewater is subsequently added according to need to maintain nutrient levels for growth of phytoplankton which provide food for the fish.

Research has provided a scientific basis for the key parameters in wastewater-fed aquaculture practice developed earlier by farmers (box 1).

Box 1. Key parameters in wastewater-fed ponds

- herbivorous and ominvorous carps and tilapias
- natural foodchain organisms – phytoplankton, zooplankton and benthic organisms
- organic loading rate 10-30 kg BOD_5/ha/day
- nutrient loading rate 4 kg N and 1 kg P/ha/day
- minimal night time dissolved oxygen of 2-3 mg/l
- maximum permissible concentration in pond water of 0.5 mg/l un-ionised ammonia.

9.1.4 Constraints

An analysis of current status of wastewater-fed aquaculture indicates various constraints. These need to be considered for each locality in which the practice is to be considered as an option. They may apply generally or be site specific:

- **lack of knowledge of most planners and environmental engineers of aquaculture as a technical option in wastewater treatment and reuse**. Conventional education in wastewater treatment rarely considers reuse of nutrients. The same applies to a certain extent to the preference of the engineering profession for mechanical wastewater treatment systems over stabilization pond systems. Mechanical systems such as activated sludge and trickling filters require much less land to treat wastewater than ponds, especially if the latter include fish ponds. Mechanical systems are usually promoted for financial reasons because land has high value in suburban areas. However, the "financial benefits" of mechanical treatment may not be realised because such plants often do not function adequately in tropical developing countries due to operational and maintenance costs . Furthermore, mechanical systems may not have a comparative advantage over ponds if a broader economic analysis is conducted to cost social and environmental factors.

- **limited available sites in periurban areas where wastewater is available for reuse.** Large-scale wastewater-fed aquaculture systems in China, Indonesia and Vietnam have mainly been developed in low lying swamps which had not been fully utilized for agriculture or urban development and which tended to receive discharged wastewater because of their low lying level. It has been proposed that urban aquaculture and agriculture be promoted using "idle land and water bodies" in periurban areas but large tracts of land suitable for the development of new wastewater-fed pond systems are becoming increasingly scarce in rapidly expanding, developing country cities.

- **rapid urbanization** in developing countries now threatens the existence of currently existing wastewater-fed system because of increasing values of land. The Calcutta wastewater-fed system has declined from 8,000 to less than 3,000 ha over the past three decades and is being maintained only through constant efforts of fish farmers and environmentalists. Rapid expansion of Ho Chi Minh City, Vietnam is leading to a decrease in the area of ponds fertilized with polluted surface water that are used to produce fish fingerlings (Photo 5).

Photo 5: Fish ponds to produce fingerlings in Ho Chi Minh City, Vietnam, being filled in for urban development.

- **rapid industrialization** provides one of the major constraints to wastewater-fed aquaculture because nutrient-rich domestic wastewater is usually contaminated with industrial wastewater containing toxic substances. This is perhaps the largest constraint in China where 75% of the total wastewater is industrial and is increasing in volume. Industrial pollution contaminates fish which become difficult to market because of unacceptable odour and taste from petroleum and phenolic compounds.

- **rapid eutrophication** from both urbanization and industrialization may constrain fish culture because of excessively high nutrient and organic matter loadings on fish ponds which cause mortality due to depletion of dissolved oxygen.

- **improved sanitation** through installation of septic tanks and sewers reduces the availability of nightsoil for agriculture and aquaculture. This may have a positive impact on public health as use of nightsoil in fish ponds poses a real although poorly documented risk to public health. A presidential decree has banned the use of the overhung latrine on fishponds in Vietnam because they are unhygienic. Ironically, this could lead to an opposite effect to the one intended and increase the incidence of unsanitary disease as the rural population does not have an acceptable sanitary alternative option to the overhung latrine.

- **social acceptance of wastewater-fed fish** There is aversion to wastewater-fed aquaculture in many societies due to a cultural taboo against consuming waste-grown produce. Perceived risk to public health may also play a role. In such societies it may be feasible to use wastewater to produce either fish seed (fingerlings) or high-protein animal feed (Figure 2.51). Wastewater-fed systems to produce high-protein animal feed consist of two sequential and therefore separate processes: resource recovery and resource utilization (Edwards, 1990b). Resource recovery involves the reuse of the nutrients contained in the wastewater as a fertilizer to produce aquatic biomass (either plant such as duckweed or animal such as fish). In resource utilization the aquatic biomass is then used either directly or as an ingredient in a feed mix to raise animals (either fish or livestock such as poultry as human food).

- **climate.** Wastewater-fed aquaculture involves the farming of warmwater organisms. Thus, the practice has greatest relevance for tropical and warm temperate climates. The need for an alternative treatment process in winter was one reason why the practice was phased out in the temperate climate of Germany.

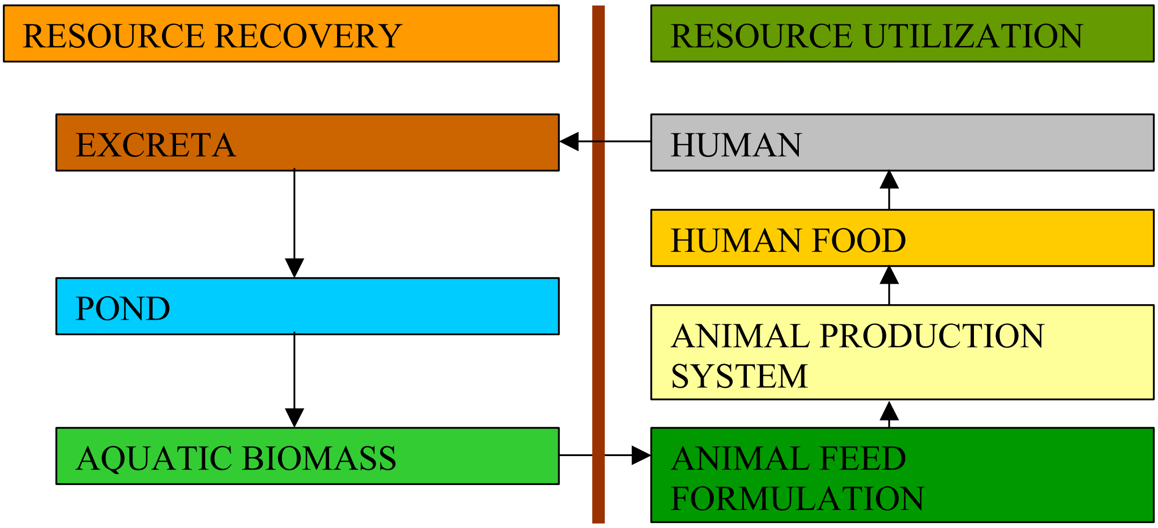


Figure 2.51: Two distinct sequential processes are involved in production of high-protein animal feed from excreta: resource recovery and resource utilization. Source: Edwards (1990b).

9.1.5 Stage of development of society

A review of the history and current status of wastewater-fed aquaculture (Edwards, 2000) suggests that it may progress through three successive developmental phases depending on the stage of development of society (box 2):

A major question is can those societies in which wastewater-fed aquaculture currently exists, and those in which it has potential, move from phase 2 to 3? Without favourable policy to recognize and capitalize on the social and environmental benefits of wastewater-fed aquaculture, and to introduce adequate environmental pollution control, the practice is likely to continue to decline. Major constraints in developed countries, which increasingly correspond to phase 3, are an increase in living standards, improved sanitation and imagined public health problems. With rising living standards there is a change in consumer preference from low-value herbivorous and omnivorous species that can be cultured in wastewater-fed systems to higher-value carnivorous fish and shrimp. This trend is being compensated for to some extent by a general increase in the price of fish so that fish species previously considered unacceptable are being marketed throughout the world. Improved sanitation is also increasingly associated with decreased availability of wastewater for reuse because of the increasing trend to install mechanical wastewater treatment systems. Perhaps the most serious constraint, despite a growing environmental awareness as educational standards rise, is the real or imagined threat to public health from pathogens and pollutants. National food regulatory agencies are likely to oppose the concept of wastewater reuse because of both public health, and social or aesthetic concerns. An example to support this contention is experience in the USA where during the 1970s several experimental waste reuse systems were studied but none have ever been implemented commercially (Ryther, 1990).

Box 2. Developmental phases in wastewater-fed aquaculture

- Phase 1 – wastewater-fed aquaculture developed in densely populated, pre-industrial societies in which limited resources favoured waste reuse. On-site sanitation or cartage and available sites also favoured the development of the practice
- Phase 2 – the installation of wastewater in early or rapidly industrializing societies initially favoured wastewater-fed aquaculture by providing a more readily available source of nutrients. However, rapid urbanization and industrialization soon limit the practice because of numerous constraining factors as illustrated by recent experience of most current systems in Asia today. Rapid urbanization leads to high opportunity cost and limited availability of peri-urban land; and hypereutrophication of surface waters may constrain the practice because of excessive organic matter and nutrient levels. Rapid industrialization without adequate pollution control leads to increasing volumes of mixed domestic and industrial wastewater streams. A policy vacuum in most developing countries limits the introduction and enforcement of favorable social and environmental legislation that would favour wastewater-fed aquaculture, including the crucial control of industrial effluents to safeguard public health.
- Phase 3 – a hypothetical late industrial phase in which there is environmental awareness in society about the need to close nutrient cycles and reuse wastewater; and favourable policy to implement industrial wastewater control and monitoring so that the practice is safe from a public health point of view.

9.2. Towards sound wastewater reuse practice

9.2.1 Public health

As discussed earlier most wastewater-fed aquaculture systems have been developed by farmers to produce aquatic produce without adequate attention to public health. Most wastewater is usually not treated prior to reuse.

There are no currently accepted international health standards for excreta reuse in aquaculture. The WHO has a tentative guideline (WHO, 1989) but it is generally considered to be unduly restrictive, thereby encouraging the continued use of unregulated wastewater reuse. Furthermore, there is a need to base health standards on epidemiological rather than microbiological guidelines i.e., on actual rather than potential risk (Strauss, 1996).

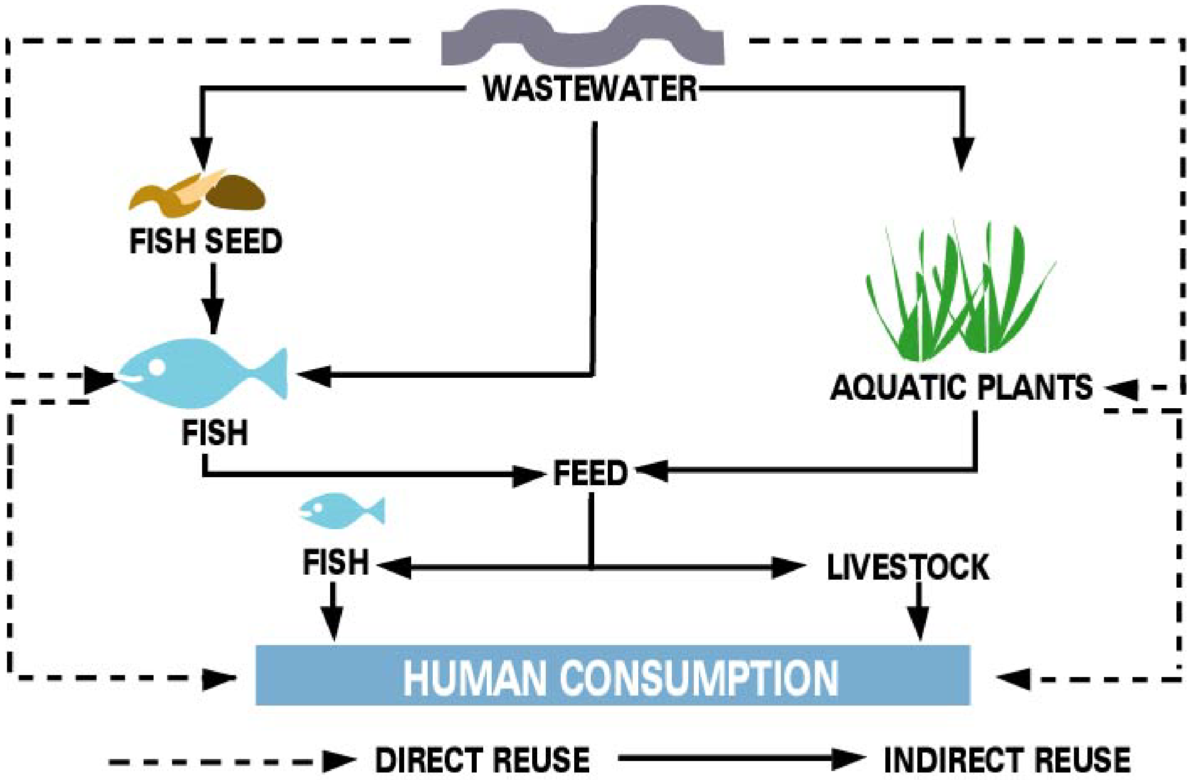


Figure 2.52: Schema of wastewater reuse strategies. Source: Edwards (2000)

Largely anecdotal evidence does not indicate a significantly increased risk to public health from consumption of wastewater-fed fish. However, scientifically based data to support this are almost entirely lacking. There is also a need to assess the occupational risk of workers in, and handlers of fish from, wastewater-fed systems. Contamination of fish with heavy metals and organics is likely unless there is separation of industrial wastewater from domestic wastewater reused in aquaculture.

A subjective assessment of health risks from pathogens and toxic substances is presented in Table 2.8. Microorganisms particularly viruses and bacteria, die rapidly in wastewater-fed ponds which explains in part why fish from such systems do not appear to significantly increase insanitary disease. Trematodes pose a significant risk in East Asia if fish harvested from nightsoil fed ponds are consumed raw. Schistosomiasis does not pose a risk to the health of pond workers because it is rare in Asia.

Table 2.8: Health risks

Health risk	Nightsoil	Wastewater			
		Domestic	Industrial	Agroindustrial	Mixed
Pathogens:					
Viruses	+	+	-	+/-	+
Bacteria	+	+	-	+/-	+
Protozoa	+	+	-	+/-	+
Trematodes	+++	+	-	-	+
Toxics:					
Heavy metals	-	-	++	+/-	++
Organics	-	-	+++	+/-	+++

Toxic substances (heavy metals and organics) probably pose a major but poorly documented threat to public health in Asia because of widespread contamination of domestic with industrial wastewater which is often reused without prior treatment.

Guidelines for domestic wastewater reuse in aquaculture have been published (Pullin *et al.,* 1992) (box 3).

Box 3 Public health guidelines for wastewater-fed aquaculture

- minimum retention time of 8-10 days for raw wastewater
- in wastewater-fed fish pond water :
    - a tentative maximum critical density of 10^5 total bacteria/ml
    - absence of viable trematode eggs
- suspension of wastewater loading to the system for 2 weeks prior to fish harvest
- hold fish for a few hours after harvest to facilitate evacuation of gut contents
- fish muscle quality :
    - < 50 total bacteria /g muscle
    - no *Salmonella*
- good hygiene in handling and processing:
    - gut the fish
    - wash
    - cook well

The guidelines relate to microorganisms and parasites. Total bacteria does not refer to total coliforms or to faecal coliforms but to SPC/ml (Buras, 1990). Although *E. Coli* was present in high concentrations in fish pond water in ponds overloaded with wastewater, it was not always recovered from fish organs and very rarely from their muscles. It seems as though it was not performing the role of an indicator organism so it was suggested that *E. coli* should not be used as an indicator for the microbiological quality of fish grown in wastewater-fed fish ponds (Buras, 1990). Fish and other aquatic organisms cultured in wastewater should be monitored to ensure that concentrations of contaminants are within international and national safety limits.

9.2.2 Opportunities for wastewater-fed aquaculture

Although a review of experience of wastewater-fed aquaculture indicates static and declining practice overall (Edwards, 2000), there are opportunities for its incorporation into existing and proposed improved sanitation schemes:

- **Developing countries which cannot afford mechanical wastewater treatment schemes.** Stabilization pond systems are more effective than mechanical systems in terms of pathogen removal although they may be less effective in terms of producing an effluent with a low suspended solids content because of the growth of phytoplankton under ambient light. Incorporation of fish culture into waste stabilization ponds systems will require extra land than for treatment of waste alone but will produce a higher quality effluent and therefore better safeguard the environment. Duckweed-based wastewater treatment systems produce an effluent with a low suspended solids content because plant cover shades the water column. Wastewater reuse systems also provide increased employment to hire local people, and generate revenue from sale of produce, which can be used to subsidize, in part, the wastewater treatment.

- **Arid and semi-arid countries have an increasing need to reuse water as well as nutrients contained in wastewater.** Pilot projects on culture of fish in treated stabilization pond effluents have been successfully completed in arid areas in Egypt in the Middle East (Easa *et al.,* 1995; Shereif *et al.,* 1995) and in the coastal desert of Peru (Cavallini, 1996) in Latin America (box 4) (Photo 6).

  Fish farming has become the main hope of the Egyptian government to achieve its animal protein production targets for the rapidly increasing human population. Local authorities have prohibited the use of freshwater for aquaculture, and even drainage water, in some regions. The aquaculture authorities have therefore directed their efforts towards obtaining a new water resource by the reuse of wastewater. It has been predicted that the reuse of wastewater will increase drastically in Egypt because of continued population growth, shortage of arable land, and a chronic scarcity of fresh water.

Photo 6: A pilot project to culture fish in treated wastewater in Peru

Box 4. Feasibility of fish culture in treated effluents of wastewater stabilization ponds in Lima, Peru. Source : Cavallini (1996).

A United Nations Development Program / World Bank sponsored project successfully demonstrated the culture of the fish tilapia in tertiary treated effluent at the San Juan stabilization ponds in Lima to produce food and employment as well as to improve the efficiency of water use in a desert environment. Fish grew well, attaining a marketable size of 250 g in 4 months, and a pond carrying capacity of over 4 tonnes fish/ha without use of supplementary feed. Analyses indicated that fish were acceptable for human consumption with respect to standards for viruses, bacteria and parasites, as well as heavy metals, pesticides and PCBs. Wastewater-fed fish were acceptable to Lima city consumers even though they were aware of the origin of the fish. It was estimated that a commercial farm in the tropics of 18 ha may produce 127 tonnes of tilapia annually at a rate of 7 tonnes/ha. Sale of fish would cover the entire treatment cost for a 100 l/sec conventional wastewater stabilization pond treatment plant using primary and secondary treatment located in an arid area with land of no commercial value. The corresponding figures for a subtropical area are a 32 ha farm producing 106 tonnes fish annually at a rate of 3.3 tonnes/ha.

9.2.3 Culture systems

Wastewater should never be reused without prior treatment if the produce (fish or aquatic vegetables) is intended for direct human consumption.

Conventional designs for wastewater reuse in aquaculture incorporate complete treatment of the effluent because it is fed to fish ponds. Thus, there is a series of anaerobic, facultative and maturation ponds before the effluent is reused in a fish pond. While the treated effluent would conform to the WHO tentative guideline of 1 x 10^3 faecal coliforms/100 ml (WHO, 1989), there would be only minimal reuse of nutrients in the wastewater because of the high degree of treatment before the effluent enters the fish ponds.

An improved design has been proposed (Mara *et al.,* 1993; Mara, 1997) which provides minimal (but adequate) treatment of wastewater and maximal production of microbiologically safe fish (box 5). This was developed to unify the approaches of sanitary engineers and aquaculturists to wastewater-fed aquaculture design. Less than 10% of the total pond area is used for pretreatment, with far more of the nutrients contained in the wastewater used to produce fish than in the conventional design. The design criterion for the fish pond is a nutrient surface loading rate of 4 kg total nitrogen/ha/day, with the number of faecal coliforms estimated in the pond water to be ≤ 1 x 10^3 / 100 ml. Thus, the microbiological quality of fish pond water rather than the pretreated wastewater influent to the fish pond complies with the tentative WHO guideline for faecal coliforms. This takes into consideration the extremely rapid die-off of faecal coliforms, which are indicators of pathogenic bacteria, in fertile wastewater-fed fish ponds. There is still a sufficiently long retention time in pretreatment to eliminate human trematode eggs.

Box 5. An improved design to simultaneously optimize wastewater treatment and fish production in a practical way. Source: Mara (1997).

Design assumptions are based on typical conditions in tropical West Bengal, India with a unit wastewater flow of 1,000 m^3/day of 200 mg BOD_5/l containing 5 x 10^7 faecal coliforms/100ml. An anaerobic pond, area 2,500 m^2 and retention time of 1 day is followed by a 26,000 m^2 facultative pond with a retention time of 4 days. The fish pond has an area of 311,000 m^2 and a retention time of 34 days. Only 8.5% of the total pond area is used for pretreatment. A yield limit of only 5-7 tonnes/ha is currently obtained on the better managed farms in Calcutta because of constraints to management of large ponds ranging in size up to tens of hectares. A new management strategy involving single stock and single harvest of smaller, 0.5-1 ha ponds which could be drained every 3-4 months and turned around quickly, could increase productivity by 2–3 times that currently achieved with corresponding gains in profitability of wastewater reuse and welfare of fisheries workers.

Most wastewater reuse is direct to produce fish or aquatic vegetables without any intervening steps for human consumption (Figure 2). In societies in which direct reuse of wastewater is socially unacceptable, it may be appropriate to promote indirect reuse to increase social acceptance of the practice. Wastewater may be used to produce either fish seed, or fish or aquatic plants as animal feed. Such systems incorporate an extra step in the food chain. Although they are likely to be less ecologically and economically efficient than direct reuse, by “lengthening the food chain” wastewater reuse becomes indirect and perhaps feasible in societies in which direct reuse is socially unacceptable.

Wastewater may be used to culture fish seed (fingerlings) which can then be on-grown for human food in separate culture systems that do not involve wastewater reuse. The major source of tilapia seed in Vietnam is a series of ponds fertilized with contaminated surface water in the suburbs of Ho Chi Minh City.

Alternatively, wastewater may be used to culture fish or aquatic plants as animal feed. Wastewater-fed fish could be used as an alternative high-protein source for diets of livestock and high-value carnivorous fish and shrimp. A significant percentage of the protein in formulated pelleted diets is fish meal. Marine capture fisheries are the main source of fish meal but production is static or declining because of overfishing. Fish cultured in wastewater may play a role in the future to augment the supply of fish meal. This is particularly true for tropical developing countries, many of which import significant quantities of fish meal to culture large amounts of penaeid shrimps. Research has already demonstrated the feasibility of production and reuse of tilapia raised on septage as a high-protein animal feed (Box 6).

A second indirect strategy to reuse wastewater to produce high-protein animal feed is cultivation of duckweed (Iqbal, 1999). Cultivation of duckweed in ponds fed with nightsoil or contaminated surface water is a traditional Chinese practice. In China duckweed is raised to feed the fingerlings of grass carp before they are large enough to consume grass. There has been considerable experimentation, and establishment of pilot projects in several countries to cultivate duckweed on wastewater to feed to Indian major carps and tilapias as well as poultry and pigs. Duckweeds have several favourable attributes for culture as high-protein animal feed (Box 7) but their continuous cultivation over extended periods of time is not easy (Edwards, 1990b).

Box 6 Wastewater-fed fish as high-protein animal feed. Source: Edwards (1988).

Three earthen ponds of 0.17 ha area were fertilized with septage at an organic loading rate of 150 kg chemical oxygen demand/ha/day. This was equivalent to a total nitrogen loading rate of 5-8 kg/ha/day. The pond was seined at 2-4 week intervals to harvest fish from the freely breeding population of tilapia. Harvested fish were small because of breeding in the pond but size of fish harvested for animal feed is unimportant. Mean net yields averaged almost 7 tonnes fish/ha/year. Feeding wastewater-fed tilapia to carnivorous fish indicated that they were as effective as marine trash fish fed directly to fish and as fish meal in formulated fish diets.

There are duckweed-based, wastewater treatment systems (Alaerts *et al.,* 1996; Poole, 1996). A complete cover of weed serves to remove nutrients from the wastewater stream and also leads to an effluent with a low suspended solids content because of shading of the water column. A USA based company has patented a duckweed based wastewater treatment system although the duckweed plant is not reused. Similar systems have been established by the NGO PRISM at Mirzapur, Tangail district in Bangladesh and duckweed from these systems are harvested and fed to fish in adjacent fish ponds (Case Study 3).

Box 7 Duckweed as high-protein animal feed

Advantages
- high crude protein content of 25-45% on a dry matter basis, although less true protein
- high growth rate of 10-40 tonnes dry matter/ha/year on nutrient rich wastewater
- ability to grow in shallow water and shade
- harvested easily by net and pole
- readily consumed by fish and poultry

Disadvantages
- growth is adversely affected by
  - low temperature
  - high temperature
  - high light intensity
- occasionally infested with insects
- difficult to dry
- decompose rapidly

9.3 Case studies

3.1 Case Study 1 – Hanoi wastewater-fed aquaculture system

Hanoi, the capital of Vietnam has a major system of wastewater reuse involving vegetables, rice as well as fish in low lying Tranh Tri district which lies to the south of the city (Photo 7). Produce from the reuse system provides a significant part of the diet of the city's people (Vo, 1996).

Photo 7: Raw wastewater being pumped into wastewater-fed fish ponds in Hanoi, Vietnam

Construction of sewers began in the colonial era in the last century and continued following independence in 1954. Wastewater and stormwater are discharged untreated, about 320,000

m^3/day, to four small rivers which play a dual role: drainage of wastewater from the city; and wastewater supply for reuse in agriculture and aquaculture. Conventional wastewater treatment plants have been constructed but lie idle due to lack of budget for operational and maintenance costs. About one-third of the city is sewered. The wastewater is 75-80% domestic and 20-25% industrial.

The system has largely been developed by the district farmers and local community over the past 30 years. Before 1960 the area was a sparsely populated swamp where rice was grown but with low yields and frequent flooding. Aquaculture began to develop in the early 1960s with the construction of an extensive irrigation and drainage system to facilitate rice cultivation. Farmers began to stock seed of wild fish collected from the river in rice fields as they perceived the benefits of wastewater-fed aquaculture. Following the formation of cooperatives in 1967, land use stabilized into vegetable cultivation on higher land, rice/fish cultivation on medium level land, and year-round pond fish culture on deeper land adjacent to the main irrigation and drainage canals. Wastewater-fed aquaculture became the major occupation of 6 cooperatives with easy access to wastewater and a minor occupation of 10 others out of the total of 25 district communes.

The local aquaculture research institute provided seed of exotic fish species, and fish hatcheries and nurseries were developed by farmers. Farmers also learned how to regulate the introduction of wastewater to produce fish. The major species are silver carp, rohu, and tilapia. Rohu has been the most popular species in recent years following its introduction in the late 1980s, displacing silver carp. However, tilapia is growing rapidly in popularity with the recent introduction of improved strains. Yields of fish of 3-8 tonnes/ha are harvested annually, lower yields from rice/fish and higher from pond culture.

The district will retain the same land use pattern of agriculture and aquaculture according to the Master Plan for the development of Hanoi city to 2010. This should diminish the threat of urban encroachment. An on-going project to improve the wastewater and drainage system of Hanoi has had only marginal impact on the wastewater-fed fish ponds through loss of a small area to construct a reservoir. The reservoir constructed to reduce flooding by storing wastewater and stormwater during heavy rain, is located downstream from the wastewater-fed pond system. A new industrial development area is being established outside the drainage area of the district so fish being cultured on city wastewater should be relatively free of contamination. However, the change in land use policy since the 1980s from cooperative to individual household management has adversely affected wastewater fed aquaculture. Over the decade since 1985 the area of wastewater fed aquaculture (essentially the rice/fish system) has declined in area by 36% from a total of 750 to 480 ha. In contrast to wastewater-fed fish ponds which are located adjacent to the main wastewater canals, rice/fish farms are unable to obtain sufficient wastewater. This is because of the breakdown in the wastewater distribution system which was previously operated by the communes.

9.3.2 Case Study 2 – Wastewater-fed fish culture

The largest, single wastewater-fed aquaculture system in the world lies to the east of Calcutta, West Bengal, India in an area locally called the East Calcutta Wetlands (Photos 8, 9). The system, developed by farmers in the first half of this century, has been well documented (Ghosh, 1990) with a view to preserving its benefits for the city and replicating the experience elsewhere (Ghosh, 1998).

Photo 8: Wastewater-fed fish ponds in Calcutta, India. A canal system to distribute untreated wastewater to the fish ponds is in the foreground and center.

Photo 9: Harvest of a wastewater – fed fish pond, Calcutta, India

An improved wastewater-fed aquaculture system inspired by the Calcutta experience has recently been implemented in three smaller cities in West Bengal (Ghosh, 1995, 1998) as part of the Ganga Action Plan, which aims to improve the water quality of the River Ganges (Photos 10,11).

Photo 10: Pumping wastewater into an anaerobic stabilisation pond at Bandipur, West Bengal, India

Photo 11: A fish pond fed with treated wastewater at Bandipur, West Bengal, India

Calcutta system

The wastewater-fed fish ponds currently occupy an area of about 2,500 ha although they extended over an area of 8,000 ha up to the late 1950s. They are located in a 12,000 ha waste recycling region for Calcutta city which also includes cultivation of vegetables on wastewater and garbage, and paddy fields irrigated with fish pond effluent (Figure 2.53). The wastewater-fed fish ponds have been developed by farmers over the past 60 years who learned by experience how to regulate the intake of raw sewage into ponds to culture fish.

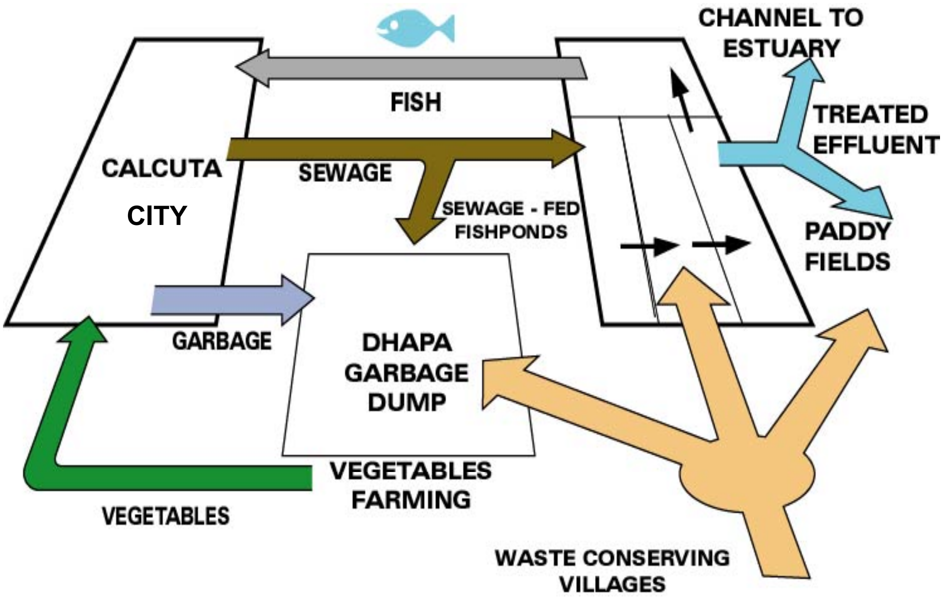


Figure 2.53: The waste reuse agro-ecosystem of the East Calcutta Wetlands. Source: Patnaik (1990).

Calcutta has no wastewater treatment plant and much of the sewage flows untreated into estuarine waters. The main sewers of Calcutta began to function over 100 years ago in 1875. Both sewage and stormwater were discharged through an outfall into a river just outside the city. However the river silted up over the next few decades which lead to the construction, between 1935 and 1940, of sewage and storm water channels, leading to estuarine waters 30 km to the east of the city which receive untreated effluents.

About 1930 a landowner discovered he could cultivate fish by letting in wastewater to what was then still a swamp. Soon a large area was converted into wastewater-fed fish ponds. As the sewage or dry-weather flow (DWF) channel usually runs at a higher level than the storm-water flow (SWF) channel, they provide a gravity feed system for the farmers to add sewage to, and drain water from, fish ponds. The area of fish ponds expanded to about 8,000 ha at its peak in the 1950s.

As the wastewater-fed fishponds extend from the outfalls of the DWF and SWF channels (both of which now convey untreated wastewater), the wastewater is essentially raw. Drainage and preparation of ponds for fish culture is carried out during the coolest months. Primary fertilization involves filling the ponds with raw sewage and allowing it to undergo natural purification for 20-30 days before fish are stocked. Secondary fertilization consists of introduction of small amounts of wastewater throughout the fish culture cycle to maintain growth of plankton to feed the fish, periodically in small ponds and almost continuously in large ponds. Water may be drained from ponds by gravity to avoid flooding. Major cultured species are Indian major carps, Chinese carps and tilapias. Multiple stocking of fingerlings and multiple or periodic harvesting of fish leads to relatively high yields of 3-8 tonnes/ha/year.

There are different types of ownership of wastewater-fed ponds. The majority are under private ownership, often by absentee landlords. There are a few cooperatives and two farms are run as corporations by the West Bengal state government.

The area of wastewater-fed ponds has declined over the past 30 years, mainly due to urban expansion. Currently they provide employment for 17,000 poor fishermen and produce 20 tonnes fish daily. Much of the harvest comprises fish < 250 g which are purchased by poor urban consumers. They provide a low-cost, natural wastewater treatment and reuse system for a city that lacks conventional wastewater treatment plants. The area of low lying fish ponds also provides storm-water drainage and a green area or lung for the city. The major threat is from urbanization but industrial pollution causes contamination of fish, particularly heavy metals. Six hundred tanneries discharge 150 kg chromium daily into the wastewater stream that eventually feeds the ponds, although there are plans to relocate the tanneries. Additionally, unregulated discharge of industrial effluents from thousands of small-scale factories threatens the wellbeing of fish and ultimately the public health of urban consumers as the wastewater is not pretreated.

Ganga Action Plan

Untreated municipal wastewater contributes a major pollution load to the rivers of India. The Ganga Action Plan was introduced by the Government of India with the objective of reducing pollution from discharge of municipal effluents along the entire length of the river Ganges. In the first phase of the initiative, class 1 cities with a population of more than 100,000 inhabitants have been included in the core sector programme which covers treatment and possible reuse of municipal wastewater which were being discharged untreated into the river Ganges.

A concept of an integrated wetland system (IWS), for wastewater treatment and resource recovery through aquaculture and agriculture has been formulated based on traditional practice in the East Calcutta Wetlands. Wastewater treatment is linked to improvement of livelihoods of the local community in the rural, peri-urban area by nutrient recovery through aquaculture and agriculture. This has been accepted by the Ganga Project Directorate as a more realistic alternative to conventional mechanical treatment plants under Indian conditions where sufficient land is available. The challenge in replicating the Calcutta East Wetlands experience has been to scale down to an appropriate level i.e., the Calcutta municipal system generates about 750 million litres of wastewater daily and the total resource recovery area covers about 12,000 ha but smaller cities have a design wastewater load of less than 50 million litres per day and much smaller areas of available land for nutrient recovery.

An IWS has been developed to date in three municipalities within the Calcutta Metropolitan area at Titagarh-Bandipur, Bally - Kona and Panihati with design loads of 14, 30 and 12 mld, respectively. Resource recovery has been achieved with different levels of success but the three projects provide important lessons for the challenge of transfering traditional, ecologically sound knowledge to an acceptable technological option for wastewater treatment for policy makers, planners and engineers.

The first IWS to be constructed was at Bandipur. Wastewater from the Titagarh municipality on the bank of the river Hugly (the name for the river Ganges in West Bengal) is transported several kilometers to the project site. A series of three ponds in series were constructed in a derelict wetland. Up to half load condition (presently it is not more than 20% of the design loading rate of 14 million litres per day) pretreatment takes place in an anaerobic pond with fish culture in two sequential ponds. Under full design load condition the area for fish culture will decline as the first fish pond in series becomes a facultative stabilization pond. Effluent from the fish ponds is used to irrigate about 25 ha of rice fields, with an average production of 3 tonnes/ha without use of chemical fertilizers. About 200 farming households benefit but improved distribution of treated effluent would almost double the number of beneficiaries. Furthermore, the irrigated area will expand in future with increased wastewater flow from the municipality.

An important feature of the IWS is the participation of stakeholders: the Calcutta Metropolitan Water and Sanitation Authority, the local village authority, the fish farmer who leases the ponds, and the rice farming households. Agenda – 21 emphasized the need to institutionalize the participation of stakeholders in environmental improvement projects to achieve decentralized decision making and management, in this case empowering a rural community for wastewater treatment and reuse. Another crucial feature is the successful implementation of a revenue generating procedure that should ensure adequate management of the system.

9.3.3 Case Study 3 – Duckweed based wastewater treatment and reuse

PRISM, a non-government organization (NGO) in Bangladesh, has carried out a research and development programme with duckweed based, wastewater treatment and reuse through fish culture. There are systems fed with conventional wastewater or sewage in three districts, the largest being at the Kumudini Hospital Complex (KHC), Mirzapur, Tangail district (Photo 12). These are located in different parts of the country and serve also as demonstration and training centres. PRISM has also developed a village level sanitation system which stimulates the installation of latrines connected to small derelict ponds which are used to cultivate duckweed (Photo 13). Harvested duckweed is again used for fish culture.

Photo 12: A duckweed based wastewater treatment system at Mirzapur, Bangladesh

Conventional wastewater

The development of the first duckweed, conventional wastewater treatment system began, in 1989 at the KHC in Mirzapur. The facility consists of one duckweed covered, 0.7 ha plug flow lagoon constructed as a 500 m long serpentine channel with seven bends. It is fed with a mixture of hospital, school and domestic wastewater from some 2,350 people with per caput production of wastewater estimated at 100 l/day. The plug flow wastewater-fed duckweed pond is preceeded by a 0.2 ha anaerobic pond with a hydraulic retention time (HRT) of 2-4 days. HRT in the plug flow pond is estimated at 21-23 days. Duckweed harvested from the 0.7 ha wastewater treatment pond is fed daily to three adjacent fish ponds, each 0.2 ha.

Photo 13: Demonstration of a nightsoil – fed duckweed system for rural households at Mirzapur, Bangladesh

Wastewater treatment efficiency is excellent. The duckweed remove nutrients and the plant cover suppresses phytoplankton growth. Average removal efficiencies for BOD_5, N and P, and faecal coliforms are 90-97%, 74-77%, and 99.9%, respectively. Effluent turbidity is always below 12 NTU. The effluent is used to top up the water level of the adjacent fish ponds. The quality of the effluent is so high ($< 10^2$ FC/100 ml) it could be used for unrestricted irrigation of vegetables according to WHO standards for wastewater reuse.

The wastewater treatment system produces from 220 to 400 tonnes freshweight duckweed/ha/year (about 17 to 31 tonnes dry weight/ha/year). The fish ponds are stocked with a polyculture of Indian major carps (rohu, mrigal and catla), Chinese carps (grass carp and silver carp), and common carp. Tilapia is not stocked but fingerlings enter the ponds incidentally. Fish production varies from 10 to 15 tonnes/ha/year, about 40% of which is tilapia. Fish yields are relatively high because of frequent harvesting and addition of other feed besides duckweed such as oil cake and rice bran. Research elsewhere has demonstrated a food conversion ratio of duckweed to fish of 3.4 (duckweed dry matter and fish freshweight bases).

Over the last two years the wastewater-fed duckweed-fish system has generated a net profit of almost US$3,000/ha/year. This is about three times that of the major agricultural crop of the area, rice. The internal rate of return was 25.9%. The system could be optimized further in terms of pond design and operation because it is overdimensioned; a high degree of treatment efficiency is already attained at about 60% of the length of the plug flow pond. This case study demonstrates that it is possible to develop a wastewater treatment system incorporating fish culture that not only achieves cost recovery but derives a net profit.

Nightsoil

PRISM has also implemented a sanitation - aquaculture programme in the rural areas of Bangladesh. Over 1,000 villagers belong to almost 150 small-scale enterprises which they own and operate collectively. As there is no conventional wastewater in rural villages, latrines have been constructed around derelict or unused ponds to cultivate duckweed, which is harvested and fed to fish in separate, nearby ponds.

The latrines consist of a moulded concrete slab connected to a pipe to convey nightsoil directly to the duckweed pond. The nightsoil is discharged in the water inside a retaining basket made of woven bamboo slats. The duckweed is cultivated in derelict or unused ponds and ditches. As most are shallow and shaded, they are unsuitable for fish culture.
Most of the ponds used to culture fish have multiple ownership which often constrains productive use. Aquaculture is being promoted through the programme leading also to the construction of new fish ponds on unproductive land. Poorer pond owners now consume more fish from their own ponds and earn more income. Furthermore, the availability of fish in local markets has increased, particularly fish smaller than 0.5 kg as encouraged by PRISM which provides greater access of the poor to cheaper fish. Prior to the introduction of duckweed as fish feed by the programme, it was totally unused. Now there is an informal market for duckweed as the poor collect it from floodplains in the rainy season to sell to fish pond operators.

There are technical and social constraints to the programme. Most household ponds are seasonal and cannot be used year round for duckweed cultivation. Duckweed may not comprise the major input to feed the fish, requiring purchase of fertilizer and feed. During the dry season, the latrines may present a health hazard and require redesigning. Some of the enterprises are losing concerns, frequently due to a credit overburden because of a large initial investment for pond re-excavation or new pond construction on low-lying land. Nevertheless quite a number of the enterprises are making an annual net profit from their duckweed-based, fish culture systems. This indicates that the system, which is still relatively new, may have potential for more widespread dissemination in Bangladesh and elsewhere.

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Section 3
Regional Overviews and Information Sources

1. Africa

1.0 Introduction

There has been an increased emphasis on urban environmental management to meet the demands of a rapidly growing urban population for safe water supply, solid waste, wastewater and stormwater management services. The demand for these services has been consistently higher than their supply in Africa; resulting in a huge unmet demand. It is now well known that integrated water management is imperative for the stability and sustainable development of cities. Examples from Africa illustrate clearly that unless adequate water supply and solid waste disposal are ensured, not much progress can be made in the provision of high standard wastewater and stormwater management. Table 1.1 illustrates the point more clearly. It shows that the method used and quantity of water supplied to an area or a house reflects the kind of waste disposal system it receives. A simple water supply system is linked to basic waste removal systems. As water service improves from minimum through basic and intermediate to full service levels it is accompanied by more sophisticated waste disposal services.

Table 1.1: Relationship between water supply and sanitation systems in Africa

Service level	Water supply system (typical water supply, litres/person/day)	Sanitation service
Minimum	• Water vendors (5-50) • Tanker supply (5-50) • Water kiosks (5-20) • Public (communal) standpipes or fountains more than 100 m from house (20-50)	• Pit latrines • Bucket/Pan sanitation
Basic	• Public (communal) standpipes less than 100 m from house (20-50)	• Ventilated Improved Pit (VIP) latrines • Aqua-privies
Intermediate	• Yard tank (50) • Yard tap (50-100)	• Aqua-privy with solid free sewer • Septic tank system • Intermediate flush toilet
Full	• House connections (>100)	• Full flush sewered sanitation

We cannot assume that the Drinking Water Supply and Sanitation Decade in Africa has solved all of Africa's water and waste management problems. Evaluation of the achievements at the end of the decade shows that the percentage of water supply coverage increased to 41%.

In the urban sector, the coverage increased from 66% in 1980 to 77% in 1990. In the rural sector, however, the coverage increased from 22% to just 26%. In the sanitation sector, the 1990 increases in coverage are from 22 to 34% for the total African population, from 57 to 80% in the urban sector, but a decrease from 20 to 16% in the rural sector. Unfortunately, the situation instead of getting better, has actually become worse in a number of the countries in the region.

Table 1.2: Urban populations in selected African countries

Country	Urban Population (%) 1995	Total Population million ,1996	GNP per capita 1996	Remarks/sub-region
Congo	59	2.7	670	Central
Cameroun	45	13.6	610	Central
Central African Rep.	39	3.4	310	Central
Congo, Dem. Rep.	29	45.3	160	Central*
Djibouti**	83	0.59	--	Eastern
Kenya	28	29.1	320	Eastern
Tanzania	24	30.5	170	Eastern
Ethiopia	13	56.7	100	Eastern
Uganda	13	22.0	300	Eastern
Burundi	8	6.6	170	Eastern
Mauritius	41	1.13	3 690	Indian Ocean islands
Madagascar	27	15.2	240	Indian Ocean islands
South Africa	51	42.4 (40.6[#])	3 130	Southern
Zambia	43	9.7	370	Southern
Namibia	37	1.58	2 250	Southern
Mozambique	34	16.5	90	Southern
Angola	32	11.5	270	Southern
Zimbabwe	32	11.5	610	Southern
Botswana	31	1.53	3 210	Southern
Malawi	14	11.4	180	Southern
Mauritania	54	2.33	470	Sudano-sahelian
Burkina Faso	27	10.6	230	Sudano-sahelian
Mali	27	11.1	240	Sudano-sahelian
Sudan	25	28.9	--	Sudano-sahelian
Niger	23	9.5	200	Sudano-sahelian
Gabon	50	1.36	4 020	Western
Cote d'Ivoire	44	14.7	660	Western
Senegal	42	8.5	560	Western
Nigeria	40	115.0	240	Western
Ghana	36	18.0	360	Western
Guinea	30	6.9	560	Western

Sources: African Development bank (1998),[#] Statistics South Africa (1998), World Bank (1996).

Note: * DRC has been recently admitted into SADC, thus becoming part of southern Africa economically while remaining geographically in Central Africa.
**The sanitation situation in the city state of Djibouti is unique in Africa. It is a best practice example; the problem in showing it off being the incomparably small scale of its operation.

It is convenient and helpful to divide Africa into sub-regions for the purpose of considering wastewater and stormwater management. The six sub-regions are Southern Africa, Sudano-sahelian zone, humid Western Africa, Central Africa, Eastern Africa, and the Islands of the Indian Ocean. Urban transition is under way in Gabon, South Africa and Mauritania where 50-54 % of the total population lives in urban areas; and in the Congo with 59 % urbanization. Table 1.2 shows the percentage of urbanization for other selected countries. It also shows the total populations and gross national product (GNP) which when used in combination provides at least indicative information about how many people need to be served ultimately as well as the internal resources available for doing so in a sustainable manner.

It is also important to look ahead a couple of decades with regard to urbanization in the sub-region. The number of small towns (population <100,000) is expected to grow from 3,000 in 1990 to 9,000 in 2020. Almost one-third of Africa's urban population will live in such towns. The number of medium towns (population 100,000 - 1 million) will likely reach 660 in number by 2020 and house 30% or about 175 million of the region’s urban inhabitants. Large cities (population >1 million) are expected to be about 70 in number by 2020 and will house some 40% of Africa’s urban population.

1.1 Wastewater characteristics (Topic a)

Waste from urban and dense settlements generally reaches the larger water environment in four waste streams:

- Sewage waste
- Grey water
- Stormwater, and
- Solid waste /litter

In Africa, the smaller proportion of the population who have in-house water supplies generate more grey water per capita. The more affluent communities generate even more grey water. Moreover, the very tiny ratio of Africans who are connected to piped sewerage system produce more sewage wastewater. Seepage from pit latrines in areas of poor sanitation services may pollute groundwater. In Southern Africa, the following figures shown in Table 1.3 appear typical for both human excreta (to VIPs) and grey water (disposed of to the ground surface).

Table 1.3: Typical figures for human excreta and greywater disposal in Southern Africa

Variable	Human excreta	Grey water
COD	100g/person/day	200mg/l
Total N	10g/person/day	20mgN/l
Total P	2.5g/person/day	31mgP/l
Water consumption	30l/person/day	-

Three chemical indicators, chemical oxygen demand (COD), nitrogen and phosphorus were traced by modelling from their source in human waste to their final destination in groundwater or surface water. The approximate loadings by sanitation type are shown in Table 1.4.

Table 1.4: Average chemical loadings* (kg/annum) depicting relative impacts of sanitation systems in South African urban areas

Sanitation system	COD	Nitrogen	Phosphorus
Water-borne	280	100	60
Septic tank	400	155	19
VIP	450	169	20
VIP + GW	640	180	52
Storm	1120	77	11

Source: Water Research Commission (1993)

Note: *The loadings represent model estimates for a typical household.

In Kenya, the characteristics of sewage for Nairobi and Nakuru are shown in Table 1.5. The per capita BOD_5 loading is also shown for Kenya and Zambia in Table 1.6.

Table 1.5: Sewage characteristics (mg/l), Kenya and Zambia, 1972

Chemical/physical characteristic	Nairobi	Nakuru
BOD_5	448	940
Ss	550	662
TDS	503	611
Chloride	50	62
Ammoniacal N	67	72

Source: Water Research Commission (1993)

Table 1.6: Sewage characteristics (BOD_5 per capita), Kenya and Zambia

Location	Grams
Zambia	36
Kenya	23

Source: Water Research Commission (1993)

In Lagos, Nigeria, the 1986 edict eliminated the pail/bucket latrine and shifted the emphasis from an obnoxious collection system to holding of waste in cesspools. There is thus a respite for the population between filling and emptying of such cesspools. Millions of Nigerians living in other towns and cities still depend on unacceptable systems. Millions who live in the squatter settlements of many African cities use pail/bucket latrines. They are used extensively in the low-income high density households of Accra and Gaborone. Some 2 million South Africans still have to rely on the bucket system. In Accra the bucket/pail/pan latrine dominates that category of households (it is patronized by 22% of the low-income and 11% of the medium-income group), with night soil being collected regularly and dumped into the ocean.

In Omdurman (the Sudan) some latrines have been in use for decades; some reaching >20m in depth. In Tanzania, the pit is often 1m wide, 2m long and 3-4m deep. Muslims and most people along the coast, and in other Muslim dominated areas, use water for anal cleaning. Other people use banana leaves or other leaves, grass, corn cobs, paper, etc. The excreta and cleaning materials go into the pits. The variety of materials affects the characteristics of the resulting wastewater.

Wastewater is derived from various sources and is closely related to the quantity of water use. Put simply it represents return flow resulting from water use. In residential areas domestic wastewater is predominant, and its volume is greatly influenced by the income group and the population density. For example, the per capita wastewater flow is estimated at 260 litres per day in low density high income areas of Lagos Metropolis (Nigeria), 77 litres in medium density areas and 54 litres in high density low income areas where average density is 700 persons per ha. The average wastewater flow for the metropolis is only 115 litres/capita/day (compared to Cairo where it is 310 litres/capita/day). In 1995 the total wastewater emptied into Lagos Lagoon was 811,300 m^3 per day, of which domestic wastewater accounted for 54%. The volume of wastewater generated is expected to increase to 1,663,090 m^3 per day by 2010.

In Africa about 80% of water consumption of those connected to the sewer ends up discharged into the municipal sewer, but in semiarid and drought prone Gaborone the return flow is 50-65%. Thus, if poor people are connected in great numbers, the resultant reduced sewer flows could upset the operation of the sewer system because of too little water being used to keep waste flowing. Actually, sewer flow in Gaborone is 18,000 to 75,000 m^3 per day by a population of some 220,000. It is envisaged however that from an average water consumption of 63,100 m^3 by 2010, a wastewater of 57,180 m^3 will be generated, giving an optimistic return flow factor of 90% (UN DESD, 1996).

Estimated wastewater flows per hectare are comparatively light in most of the 21 sewerage districts of Lagos; meaning that on-site sanitation methods could cope with these flows presently. However, some three to five districts have significant wastewater flows (40 to 55 m^3/day /ha), and measures must be taken to remove the flows by appropriate disposal and/or treatment facilities. Some form of sewerage system is likely to be the only technically viable option.

Accra's formal and informal drains are filled with stormwater, septage, sullage (or greywater), and solid waste. They flood and overflow in the rainy season and become informal waste dumps, or stagnant cesspools in the dry. The result of this practice is periodic flooding that destroys properties, wastes time and causes loss of life, in addition to the environmental pollution and health hazards they present. Nearly 20% of Accra is subject to flooding. This picture of Accra typifies the mixed nature of wastewater in many African cities.

For example, in medium to high density residential areas of several African cities, such as Lagos, Dar es Salaam, Addis Ababa, open storm drains are common and in many cases act as open sewers, particularly for the conveyance of sullage (or greywater). Often too, septic tanks act as vaults, with the overflow of sullage water being discharged direct to open stormwater drains. In addition most industrial wastewater is discharged into these same drains. This practice tends to change the characteristics of wastewater drastically, and invariably compromises the function of such drains.

In Lagos, wastewater is discharged to the Lagos lagoon and even sullage (or greywater) water is discharged in open drains throughout some of the urban catchments. In the largest peri-urban settlement of Nairobi known as Kibera, drainage is virtually non-existent, and during the rains in April/May and December, the areas can hardly be walked as stormwater and sullage are of particular nuisance.

The work of Schneider (1994) in one of Lake Victoria's watersheds that houses Kenya's Kisumu town, estimates the per capita BOD_5 load from septic tanks in the town as 30 g/day, that from pit latrines as 19-22 g/day, and 23 g/day for domestic sewerage, a value that seems to typify Kenya's domestic effluents. The load associated with leachate from solid waste is also estimated at 9.0 g/c/day or 1.7 tons/day. Thus for Kisumu town a total of 6,374.11 g/day is generated and much of it subsequently released into Lake Victoria to contribute to the lake's severe eutrophication problem (Figure 1.1).

1.1.1 Stormwater characteristics

Peak flows of urban stormwater runoff may increase by a factor of 3 to 8 as urbanization progresses depending largely on the proportion of the urban watershed covered by impervious surfaces. Cases of poor land-use planning and failure to maintain drainage and other urban facilities in good conditions abound in Africa (Oyebande, 1990). These conditions often aggravate flooding and pollution hazards as reported in Ibadan, Nigeria (1984 floods), and Dar es Salaam, Tanzania (1987). The case of Gadarif in Sudan, is a real catastrophe. The urban centre lies within the Khor Abu Farga watershed. There was a population explosion and the resultant expansion of urban land-use was not properly and often informally undertaken, with many houses built in the flood plains. On September 9, 1973, a storm rainfall of 90mm occurred. The 5-year storm resulted in a 25-year flood which caused the worst damage ever reported in the Sudan to that date.

In most African urban areas the high rainfall intensities are prevalent and poor land-use planning is predominant. For instance Table 1.7 shows the relatively much higher intensities for tropical Africa than for the temperate region. Given such circumstances, the lag time in an urban area with a storm water drainage system is much shorter, being only between 12 and 20% of that of a comparable natural system. And for an increase in imperviousness of from 1% to 30% (developed urban areas), the flow rate itself increased by a factor of 9 for a 2-year rainfall event and by a factor of 5 for a 50-year storm. The corresponding total runoff volume can be double that of a natural area, hence the amplification of Gadarif flood level and disaster.

Table 1.7: Rainfall intensities of 2-year return period (mm/hr) in Africa and Europe

Duration (minutes)	5	15	30
Urban Location			
Niamey (Niger)	160	110	79
Ouagadougou (Burkina Faso)	184	128	92
Abidjan (Cote d'Ivoire)	171	142	104
Lagos (Nigeria)	150	105	95
Port Harcourt (Nigeria)	160	121	80
Montpellier (South of France)	126	69	48
Paris (France)	82	41	27
Gothenburg (Sweden, west coast)	80	20	18
Stockholm (Sweden, east coast)	60	25	18

Source: Oyebande (1983)

Urban stormwater designers and planners are having to deal with the increases in runoff volumes and peaks due to urbanization by using more sophisticated approaches for design and planning of stormwater drainage systems.

1.1.2 Impact of waste disposal options

Sewer reticulation systems (networks of conveyance pipes) particularly when inadequately maintained, as is often the case in the region, can cause substantial adverse environmental impacts. A survey conducted to evaluate the risks to the environment associated with sanitary wastes from various waste disposal technology options within South Africa is quite revealing. It shows in particular that all sanitation systems have some impact on the biophysical environment. In the case of sewer reticulation, 44% of respondents or users often experienced severe to moderate blocked sewers and over-loading/overflows. With regard to sewer blockages/overflows only 13% had no problems. Only 21% had moderate to severe problems with the operation of treatment works – hence it appears that the problems are concentrated at the reticulation or user end.

Table 1.8 shows the impairment suffered by sewerage and storm drainage systems. During the period of field work component of a study (Agbelusi, 1990) there were 49 cases of overflowing manholes, 66 cases of blocked storm sewers, 67 cases of overflowing inspection chambers and 82 cases of uncleared garbage bins. In addition some 23 areas show up as being flood prone. It is interesting that the low-income housing units suffer the least of these impairments.

The major effect of inadequately operated and maintained reticulation systems (networks of conveyance pipes) is spills which cause raw sewage to flow into rivers, impoundments and the sea. The potential negative health and environment impacts arising from this is of great concern. The severe health risks are of two kinds in the region: from pathogenic microorganisms and from chemical contaminants. The illnesses associated with the pathogenic microorganisms (parasitic worms, protozoa, bacteria and viruses) include cholera, typhoid fever, paratyphoid fever, bacillary dysentery and diarrheal diseases; infectious hepatitis, gastroenteritis and meningitis.

Table 1.8: Impairment of sewerage and storm drainage structures in Festac Town, Greater Lagos, Nigeria

Avenues	No. of closes	Overflowing manholes	Blocked storm sewers	Overflowing inspection chambers	Uncleared dustbins	Flood prone areas	Dominant housing unit
1st	35	-	-	3	2	1	L
1st	-	-	-	-	-	-	L
2nd	4	4	-	2	1	-	H
2nd	5	5	-	2	1	-	H
2nd	37	5	8	9	4	3	L/M
2nd	-	-	-	-	-	-	L
2nd	1	-	-	-	-	1	L
2nd	-	-	-	-	-	-	L
2nd	6	-	-	-	-	-	L
2nd	11	6	9	15	17	1	H
2nd	5	1	2	-	7	1	H
2nd	4	-	-	-	-	-	H
2nd	24	-	4	8	6	2	H
2nd	12	9	6	4	8	1	H
2nd	3	-	-		-	-	L
3rd	50	2	-	1	7	2	H
3rd	16	-	-	-	-	2	H/M
4th	11	-	-	-	-	1	L
4th	11	-	-	1	2	1	H
4th	9	3	4	2	7	3	H
4th	5	2	8	3	6	1	H
5th	50	3	8	5	8	1	M/H
5th	-	2	6	3	2	1	M
7th	8	2	1	-	5	-	M
7th	14	4	10	9	13	1	H
Total	320	48	66	67	82	23	

L= individual housing units; H= high density housing types, e.g. block of flats and barracks; M= medium density housing types, e. g. semi-detached or one storey buildings and medium density block of flats.
Source: Agbelusi (1990)

Angola presents a similar situation: 44% of Angola's urban population lives in Luanda and its district with 30% of the population having access to good quality water, 21% to sanitation. As a result Angola experiences a high infant mortality of 173 per 1000, caused primarily by diarrheal diseases. The linkage has inspired several studies which have made various claims of reduction in diseases as a result of improved water and human waste disposal (Table 1.9).

The chemical contamination of primary concern in sanitary wastes as encountered in onsite sanitation is nitrate. High nitrate levels in drinking water are known to cause infantile cyanosis (Fourie and van Reyneveld, 1993) or 'blue baby' syndrome.

Table 1.9: Expected reduction in incidence of diseases from improved water and sanitation

Disease	All Studies		Better Studies	
	No.	Median	No.	Median
Diarrhea mobidity	49	22	19	26
Diarrhea mortality	3	65	-	-
Dramcunculiasis	7	76	2	78
Schistosomiasis	13	73	3	77
Overall impact on child mortality	9	60	6	55

Source: Ugandan Ministry of Health (1997)

Poorly designed and constructed soakaways and VIP latrines expose groundwater to severe pollution from percolation in Lagos and other coastal areas where the water table is high.

COD contribution of storm water may greatly exceed the loadings from sanitation systems by a factor of 2 to 5 (Table 1.4). This is largely due to high non-point pollution loads, and discharge of organic and other oxidizable materials, in stormwater runoff. The choice of sanitation system will normally not have a major influence on the total COD loading into the environment, but in dry, low runoff condition, it may become important for example in the sahelian and southern Africa.

Nitrogen removal from septic tank and VIP system compares favourably with waterborne sanitation systems, where soil conditions are favourable in the region. VIP and septic tanks almost always provide greater phosphorus removal than water-borne sanitation in the absence of specially designed treatment works for the latter (Fourie and van Reyneveld, *op. cit.*). Since a number of the systems have neither disinfection nor maturation ponds, pathogenic bacteria pass straight through the system into the river, lagoon or the sea if treatment plant, pump station or the reticulation fails. This is a very serious water and environmental pollution source in many of Africa's coastal cities. Thus in case of system failure, full waterborne systems may pose the most serious threat to the environment.

Effluents from sewage disposal systems in many cities in the region contain high levels of nutrients, particularly high levels of phosphates. The enrichment of water bodies with plant nutrients has changed the trophic state of many of the rivers, canals, lakes and lagoons through eutrophication. The mats of weeds on the lagoons of the Guinea coast of West Africa and on the Victoria Lake (Figure 1.1), are just some examples of the severe environmental impact of contamination by sanitary wastes in Africa. Water sector agencies in Africa have also identified eutrophication as a culprit for increased water purification costs.

Urban stormwater runoff has become a major source of stream pollution in many areas and not just something to get rid off fast (Figures 1.2 and 1.3). Even in developed countries, for some 80% of urban areas, the downstream water quality is determined by non-point sources of pollution. In South Africa a measure of control of point sources of pollution has been accomplished with the implementation of the 1 mg/l phosphate standard in treated sewage effluents in sensitive catchments such as the Hertebees poort Dam and the Vaal Barrage catchments. Nevertheless, due to the non-point pollution loads, some 40% of the dissolved solids entering the latter barrage is attributed to stormwater runoff from the southern Johannesburg area.

Various monitoring programmes have identified plant nutrients, oxygen demanding organic compounds, toxic heavy metals, hydrocarbons, sediments, and pesticides as the culprit pollutants. Construction sites represent one of the sources of sediment in an urban environment. Stormwater in African urban environments have been found to carry toxic pollutants such as heavy metals, hydrocarbons, and pesticides. The sources of heavy metals in urban runoff include atmospheric fallout, corrosion processes, tyres, pavement wear, vehicle exhaust emissions, brake linings, paint and industrial spills and not infrequently effluent dumps or discharge.

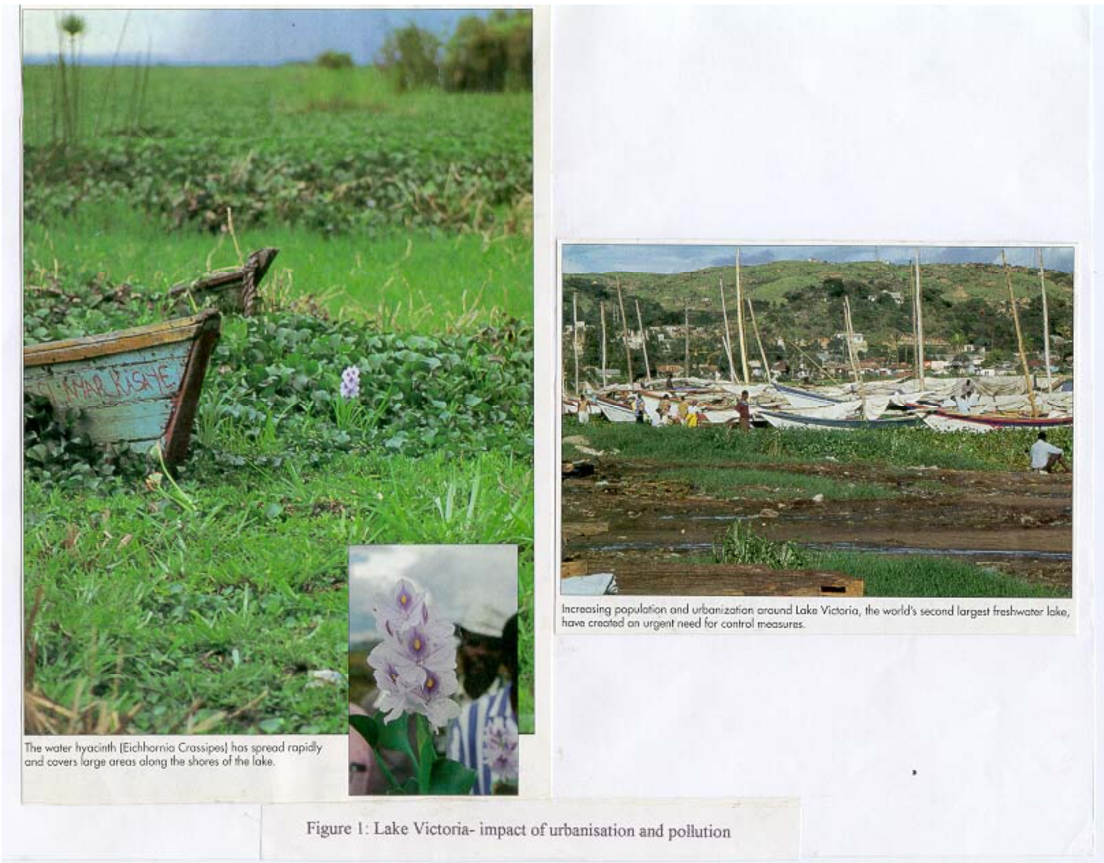


Figure 1.1: Lake Victoria – impact of urbanisation and pollution

The discharge of organic and other oxidizable materials in stormwater runoff imposes much oxygen demand on the receiving waters and results in oxygen depletion which could lead to anaerobic conditions (Coleman, 1993).

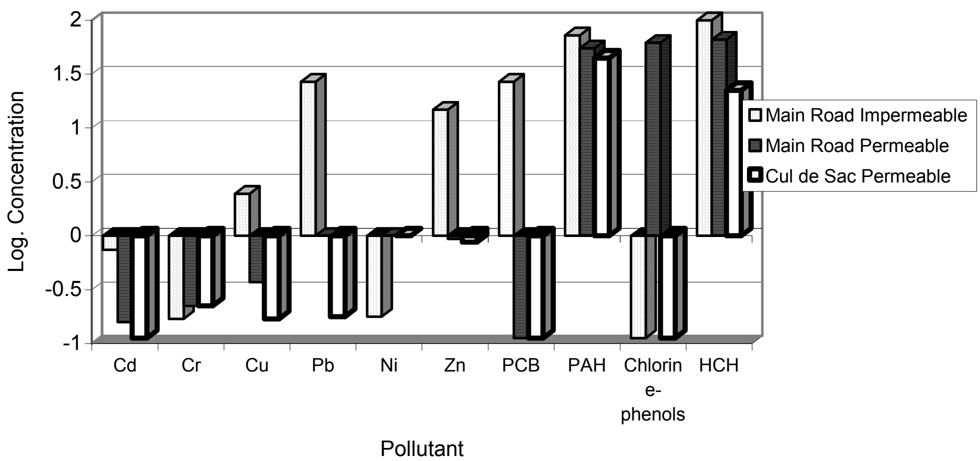


Figure 1.2: Quality of stormwater runoff from roads.

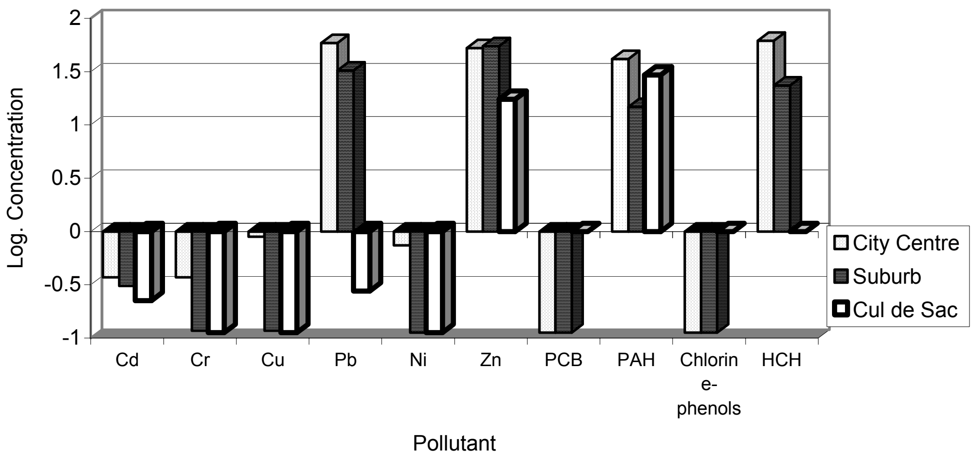


Figure 1.3 : Quality of stormwater runoff from roofs

1.2 Collection and transfer (Topic b)

How has Africa fared since the end of the Drinking Water Supply and Sanitation Decade in 1989?

1. Coverage

Coverage refers to the percentage of the population that has access to collection and disposal of wastewater, with or without treatment. Table 1.10 indicates that sanitation coverage in the sub-Saharan Africa (SSA) increased from 28% in 1980 to 36% in 1990. Today, access to adequate excreta disposal is available to only about 35% of the population. Technologies used for the safe disposal of excreta are mostly of the individual type, mainly septic tank system and simple latrines. Communal systems, such as conventional and small bore sewers are rare, and available in some urban high income areas only.

In communities where space is lacking, or no nearby reliable water supply is available, the feasibility of water borne sewerage or even pourflush latrines becomes questionable. Households seem to be more aware of these limitations than many technical agencies. For example, in Kumasi, Ghana, more than 50% of households preferred a ventilated latrine to a water-flushed toilet, because the former does not depend on water, is simple and does not break.

The population of Botswana is over 200,000 and still growing at 12% per annum. The capital Gaborone is fully sewered, but roughly half of its households have chosen not to connect to it. This is largely due to affordability, for in-house water and sewerage connection raises SHHA plot cost by 18%.

Table 1.10: Water supply and sanitation coverage in Africa

(a) Coverage for all sanitation types

Water (%)			Sanitation		
1980	1990		1980	1990	
32	46		28	36	

(b) Coverage of full waterborne sewerage connections in some countries

Country/urban centre	% population connected	Remarks
Botswana/Gaborone	50	Available access is 100%; length of sewer is 1.85 km /1000 persons
Ethiopia	7	% of national population
Ethiopia/Addis Ababa	12	
Ghana/Accra	3.3	See Table 10.
Kenya/four towns	100	DANIDA project: Busia, Homa Bay, Isiolo and Nyahururu .(See Table 22).
Malawi/all urban areas	15	1987
Nigeria/Abuja	Wupa100; whole territory (75)	Abuja City in Wupa drainage district houses 200,00 people.
Nigeria/Lagos	5	Metropolitan Lagos.
Nigeria/Lagos/Festac Town	100	Population of 90,000
South Africa/all towns and cities	64.2	Ratio of all urban population (totalling 24.5 million in 1990.
South Africa/North Cape	29.9	For the whole province.
South Africa/Western Cape	85	Out of a total urban population of 3.156 million in the province.
Zimbabwe/Harare	~ 100	High income dwellers who have large plots of ≥2,000m^2 are allowed to have preferred septic tanks; length of sewer is 4.1 km/1000 persons

Note: Blantyre and Lilongwe each has a water board. Donor environment appears favourable: as many donor organizations have provided financial assistance through grants and loans The donors include World Bank, UNICEF, UNDP, USAID, DANIDA, EEC, ADB, CIDA, British and French governments.

In 1992 per capita water consumption in Harare was 73 l/c/d for high density, 200 for medium and 311 for low density residents. On the average Harare water users pay \$0.15/m^3, less than 25% of the real marginal cost of the water. The price of Harare water is based not on its cost, but on the anticipated annual expenditure.

Virtually all the inhabitants of Harare's recognized residential areas – low and high density – have access to water-flushed toilets and almost all those who need to be connected to sewers are connected. High income dwellers who have large plots of 2,000m^2 or more are allowed to have septic tanks if preferred. This is an achievement not matched by any city with such a low GDP per capita.

When Gaborone was established in the mid-1960s, practically the whole of it was sewered by a system of gravity sewers, with treatment facilities in a series of waste stabilization ponds. Everyone could be connected to the sewer system, but not all have been connected. The non-SHHA plots with roughly 50% of Gaborone's population, have water-borne flush toilets attached to the sewer system. The SHHA plots (low-cost or low-income housing) with the other half of the population, have pit latrines in their yards.

The core of every SHHA plot not connected to the sewer seems to be the VIP toilet. Sludge removal frequency is once in 2-5 years, but in Gaborone, some pits have to be emptied once a week and many of them once in a year.

Both Harare and Gaborone are fully sewered in the sense that almost everyone could be connected up to the existing system. The length of sewer system in Harare is 4.10 km per 1000 population, and Gaborone 1.85 km per 1000 persons.

The population of Addis Ababa is some 2.113 million. A sewerage system was commissioned in 1981 to serve only the central part of Addis Ababa. It is a small system with a capacity to serve only 200,000 users, but is not operating at full capacity. The treatment plant is located at Kalitie and was designed for just 50,000 people, but can be expanded to serve 100,000 and then 150,000-175,000 (World Bank, 1997).

The excessive growth of Dar es Salaam (8% p.a.) over-stretched the drainage system and flooding frequently disrupted economic activities. In 1987 President Nyerere had to intervene personally to immediately effect maintenance work on the sewer network and drains. At that time most of the sewer network was completely blocked by materials and only 2 of the 17 sewage pumping stations were functional. Indeed, only 12% of Dar es Salaam's population had access to the choked sewers by the early 1980s while 8% used septic tanks and 80% had pit latrines (Oyebande, 1990).

1.2.2 Problems with sewers

The total cost of operating a water-flushed toilet is nearly 8 times that of a pit latrine ($5,885 to $750) in Botswana. Endemic sewer blockage could result because guidelines for sewer operation usually call for 50 l/c/d to keep waste flowing. This sums up to 7.5 m^3 per month, just to keep the sewer flowing. That amount alone is more than most families consume in a month in Gaborone (national per capita water use is 175 litres /day, and the poorest half of the families use about 60 l/c/d). By Africa's standard this is a high level of service, yet it is hardly adequate to operate water-bone sewage system for half of the population. It is perhaps obvious sewerage systems may not be generally sustainable in most African cities. In South Africa some 31% of the urban population have inadequate sanitation. Most of its communities desire raw waterborne sewage systems as their first choice, but adequate funds are not available to provide this system to all in need of sanitation facilities. The country has therefore developed increasing interest in alternative technologies, e.g. settled sewerage systems that provide for flush toilets but have lower cost implications.

In Africa about 80% of water consumption of those connected to the sewer ends up discharged into the municipal sewer, but in Gaborone, the return flow is 50-65%. This is why it is feared that if poor people are added in great numbers, the resultant reduced sewer flows could upset the operation of the sewer system because of too little water to keep waste flowing. The ultimate solution perhaps lies in the pursuit of lower cost alternative technologies that suit this water short Region which is much drought prone.

A full waterborne sewerage system was installed by Ghana Water Sewerage Corporation in central Accra with World Bank assistance and completed in 1973, covering 1000 ha and involving 28.5 km of sewers. It is a classic example of unaffordable services by prospective beneficiaries. The system never worked well, because of narrow and crooked streets and below standard housing and plumbing that exist predominately in central Accra hampered connection to the system (Poster et al., 1997). Table 1.11 shows that only 6.5% of the available connections were utilized. The old agenda of supply driven sanitation system wasted immense investments. Inappropriate designs, neglect of user requirements, inadequate maintenance, and ill-equipped operating agencies create continuous drain on government resources, and a disincentive to governments and donors contemplating further sector investment. Users become disillusioned when promised improvements fail to materialize, and refuse to pay for inadequate services which leads to further deterioration.

Table 1.11: Sewerage systems not adequately patronized by intended beneficiaries

Country (city)	No of year since commissioning sewerage system	No. or % of connections made	System capacity (No. of available connections)
Ghana/Accra	20 years	130 nos.(6.5%)	2,000
Ethiopia/Addis Ababa	10 years (16 years in 1997)	10% (60%)	-

Source: Wright, A.M. (1997)

The existing waterborne sewerage schemes in Greater Lagos are in various states of disrepair and operational conditions and are of three categories:

- Housing estates – have the larger systems – Festac, Abesan, Oke-Afa, Amuwo Odofin, Iponri, Alausa Secretariat, Victoria Island, Lagos Island.
- Institutional and commercial schemes – generally much smaller and a total number of 65 separate schemes have been constructed.
- Only a small number of industries have sewerage schemes and treatment plants although the Federal Regulations require this provision: Lever Brothers, Apapa, WEMABOD plant, Ikeja.

Festac (Festival of Arts and Culture) Town, a satellite of Lagos municipality, is a “new” town built to house the participants in the World Black Arts Festival which Nigeria hosted in 1977. Thereafter it was settled. It is situated on the Lagos-Badagry road which links Nigeria with the Republic of Benin, on a land are of 770 ha. There were three communities with 4220, 4053 and 2052 dwelling units, while 1000 units were added later. Some 68% of the inhabitants belong to the low-income group (by designation, but many of them are anything but low-income group), 11% middle- and 21% high-income group. The revised plan for the town provided for a total of 61,600 persons.

The sewerage system was designed to serve the whole population of the town. Altogether there are 72 km of sewerage pipes, 24 km of open drains, 81 km of storm sewers (drain pipes), while 112 km constitute the water supply network. There are 7 pump stations, and the wastewater from the whole town is conveyed to a nearby settlement known as Sattellite Town where the treatment plant is located.

Abuja, the new Federal Capital of Nigeria is designed to be served entirely by sewerage system. On account of sharply varying topography, however, there would be some four central sewage systems (Pers. comm. Emmanuel I. Ovbiebo, 1999). The system in place now is the one serving the central city of 200,000, in the Wupa drainage basin. It is designed to have 5 treatment plants, which are under construction. The temporary plant now in use has capacity to serve only 50,000 people. Wastewater design flow is 210-230 l/c/d, but the actual flow is about 200l/c/d.

Topography favoured gravity flow at Abuja with an elevation of 495 m. The landscape slopes gently towards Abaji, one of the satellite towns at 300m, such that a lift station is required only near the plant. The sewer pipes are laid along the lowest river valleys, parallel to the main river course, and such valleys were designated green belts. But already, developers are encroaching on the green belts and tampering with the manhole and sewer pipes.

The satellite towns of Gwagwalada, Sheda, Abaji and Yanyan of the Federal capital of Abuja have central sewerage systems designed but not yet constructed. At the moment they use septic tanks which would be disconnected, and filled up with laterite when the sewerage system is ready. The question is why can't the septic tanks be sewered instead of wasting such huge investments?

Only 5% of the inhabitants of Lagos Metropolis is connected to sewerage and associated sewerage treatment plants which do not treat the sewage to acceptable standards, and are poorly maintained and operated. The Federal Government 1004 Housing Estate sewerage system is served by a package treatment plant. Breakdown of various electrical and mechanical components and lack of funds for adequate maintenance, sees the bulk of the wastewater that enters the plant by gravity sewers or discharges from vacuum trucks, bypass the treatment units and discharge untreated direct to the lagoon.

The district has one of the largest existing sewerage schemes within metropolitan Lagos, the Victoria Island sewerage scheme' though it has never been commissioned or used. It was designed in the early 1970s to cover most of Victoria Island. The following data summarize the stage of its completion as at December 1978 when all works appear to have ceased as the contractor abandoned site without notice, and never returned.

- total length of sewers laid (100 mm, 150mm 200mm, 250mm, 300mm diameter asbestos cement sewer) representing 40% completion : 23,780 metres
- total number of manholes constructed : 341
- total depth of manholes constructed representing 31% completion: 476 metres

Total wastewater flows to Lagos lagoon in 1995 and by 2010 have been estimated as in Table 1.12.

Table 1.12: Estimated wastewater flows from metropolitan Lagos to the lagoon in 1995 and 2010

	1995	2010
Population (million)	7.01	27.6
Domestic wastewater	437,490 (54%)	?
Total wastewater (m^3/dy)	811,300 (115.7 l/c/d)	1,663,087

Source: Lagos State Ministry of Environment and Physical Planning (1996)

1.2.3 Settled sewerage system

In some parts of Africa, particularly South Africa, Botswana, Zimbabwe, Cote d'Ivoire and Nigeria, interest in alternative technologies is increasing, particularly in alternatives that provide for flush toilets but have lower cost implications – settled sewerage systems.

Settled Sewerage System (SSS) is a system or network of pipes designed to convey the liquid portion of sewage to a central treatment and/disposal point. The solids in the sewage are settled out in a septic tank upstream of the pipe network. A vacuum tanker removes the sludge at intervals and transports it to the treatment works. Thus the elements of a settled sewerage system include a pedestal and a flushing mechanism, an on-site storage/settlement unit (septic tank), solids – free sewers; a mechanism for removing sludge from the on-site containers and a treatment and/or disposal facility. Currently, there are 21 SSS schemes in South Africa serving 16,000 persons since 1989 in high- medium and low-income communities (du Pisani, 1998).

The advantages of SSS include savings on capital, operation, and maintenance costs, simpler design and easier construction, as well as simpler treatment requirements than for the conventional sewage conveyance systems. Savings are estimated at between 8.7% and 43% in South Africa schemes. There are in addition savings in water supply system, water consumption and wastewater treatment. As shown below its existence elsewhere in Africa predates that of South Africa.

The system has some disadvantages as pointed out during its evaluation. There is restriction in access to the septic tanks and the cost of emptying the tanks could be substantial over time. In addition, there is still lack of understanding of the system among operators.

Settled sewage system was introduced in Zambia in the 1950's with 80 connections completed in early 1984 in the Balovale suburb of Lusaka II. It has since been extended and currently the system is among others in Ndola, Kabwe, Kafue, Choma, Kalome and Monze, Livingstone, Kitwe and Lusaka's suburb.

The Zambian systems generally drain aqua-privies and are termed "sewered aqua-privies". They are not properly maintained due to lack of manpower and equipment. Good user education is needed in order to show the way it differs from the conventional system.

Small bore sewer systems

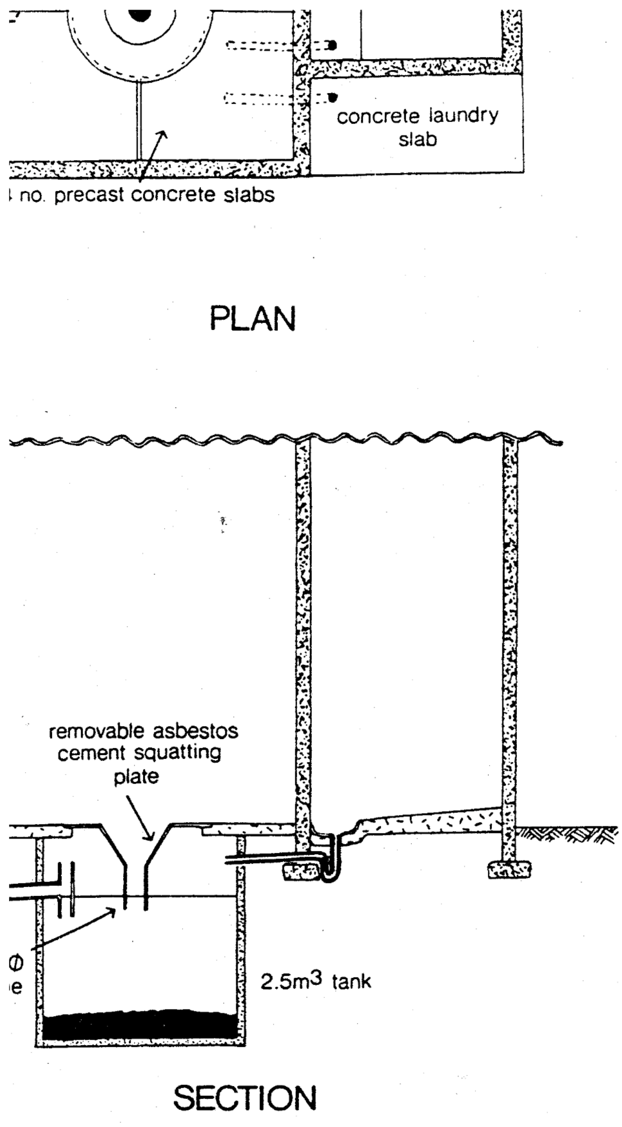
Small bore sewer systems are designed to receive only the liquid portion of household waste for off-site treatment and disposal. All troublesome solids are separated from waste flow in the interceptor tanks upstream of the connection to the sewers. The accumulated solids are removed periodically for safe disposal. For Africa, design storage is normally adequate for three years, a period sufficient to allow anaerobic biological digestion to reduce the sludge volume by up to 50-80%. The systems have advantages which include reduced water requirements, reduced excavation, reduced materials cost and reduced treatment requirements (Otis & Mara 1985). Design flows for yard tap supplies is 40-80 litres per capita per day (l/c/d), and 80-120 l/c/d for multiple tap in-house supplies. These reductions in turn result in unit cost savings of 25-50% over conventional sewerage systems in Africa.

The small bore sewer systems have proved to be especially suited to the following situations in the region:

- sewered pour- flush toilet systems provide opportunity;
- sewered septic tank systems. This could be the only feasible solution in urban areas where excessive housing densities where it is practically impossible to have individual family latrines due to space constraints, or where unsewered septic tanks would represent real health and environmental hazards. Examples of such in the region abound in the peri-urban settlements of major towns and cities in the region; 30% of Addis Ababa, parts of Greater Lagos, Kibera in Nairobi, and squatter settlements of Gaborone fall into this category.

The small bore sewer system was originally developed in the late 1950s in Northern Rhodesia (now Zambia). Conventional and sullage aqua-privies reportedly did not work well in Zambia (Otis & Mara, op. cit.); so small bore sewers were installed to remove the settled wastewater from the aqua-privy tanks. They were designed for a minimum daily peak flow of 0.3 m/s, and the pipes were 100 mm minimum bore and laid at a gradient of 1 in 200. A well known

Zambian example is that at Chipanda in Matero Township of Lusaka, but there is another one in Ndola.



gure 4. Sanitation block in New Bussa, Nigeria

The sewered aqua-privy system served 532 one- or two -bedroom houses in the Chipanda low-income housing area in 1978. Each aqua-privy block serves four contiguous households. Each household discharges its sullage into the aqua-privy tank from where the effluent is conveyed via a 100 mm asbestos cement (AC) connector pipe into a 150 mm AC lateral sewer which runs between the compounds. The latter discharges into a 225mm main sewer, and thence into a 600 mm trunk sewer. The latter two sizes of pipes were designed as part of the Lusaka conventional sewer system.

In Nigeria, there is a small bore sewerage system, the sewered aqua-privy in the town of Bussa, built to resettle those displaced by the reservoir created by Kainji Dam, opened in 1968. The system was constructed in 1964 and serves 256 enclosed family compounds, each housing 15-40 people, in Kwara State (Feachem et al., 1979). Each compound is served by a sanitation block comprising a laundry, shower room and an aqua-privy compartment (Figures 1.4 & 1.5). From the water tap in the laundry sullage is discharged into the aqua-privy tank which in turn discharges into a 100 mm diameter asbestos cement pipe. This pipe is connected via a street junction box to a 100mm or 150 mm diameter collector sewer which runs in the lane or street outside the compound. The wastewater is treated in one of two facultative waste stabilization ponds serving the east and west of the town.

It is reasonable to assume that the hydraulic design of the small bore sewers was based on the Zambian model and is therefore very similar, though some design details differ. In spite of the problems associated with the intermittent supply of water, connector sewers, frequency of desludging of the aqua-privy tanks, user satisfaction was generally found to be high.

The total construction cost (the sanitation block, small bore sewers, ponds) was about US$408 (1978 value), that is, a per capita cost of about $13.6 for a compound of 30 residents.

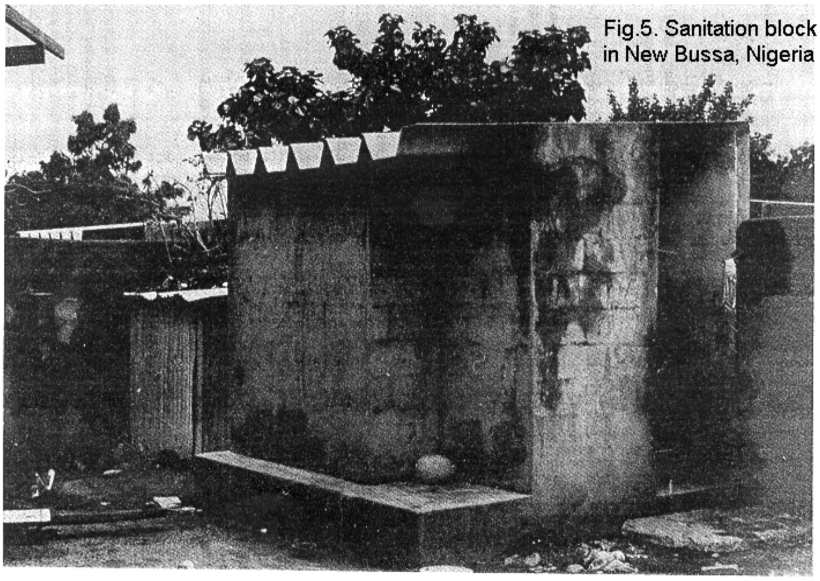


Fig.5. Sanitation block in New Bussa, Nigeria

1.2.4 Stormwater

How can stormwater be managed to improve its quality? In principle the policies in Africa are aimed at accomplishing, but the results obtained often belie the approach:

- control of sources of pollution e.g. removal by street sweeping, and catch basin cleaning, by detention storage and filtering, odour controls.
- Runoff treatment involves use of detention ponds and diversion.

Stormwater management is a relatively new field in many parts of Africa. The immediate problem in planning and designing urban centres with respect to stormwater is how to remove the stormwater with minimum cost. Nevertheless urban storm runoff is a resource and should not be treated as a common enemy to be sent downstream as fast as possible (Wright 1971).

At the same time urban flooding is no longer be accepted in Africa as an inevitable hazard to be tolerated calmly. Compounds of storm management include:

- Design alternatives – e.g. retarding or retaining storm runoff to reduce peak, to elongate design storm duration and lower design storm intensity – thus making savings in conduit, etc.
- Catchment management – to minimizes runoff peaks and volumes and to preserve the basin environmentally.

Table 1.13 contains a list of stormwater management practices.

Piped drainage and open-ditch drains both make up Addis Ababa's drainage network. The piped drainage is constructed along the main asphalt roads by the municipality. The open ditches are constructed mostly either stone-paved or excavated natural ditches by the municipality and NGOs with national and international affiliation. The stormwater drainage system is inadequate. Whole sections of the city, central zones included, lack open paved ditches. The quality of the existing works is poor because of lack of tie-ins at the trunk level. The open ditches are also commonly used to drain off wastewater and dispose of solid waste, thus compromising their function.

Roads are built without any drainage works, thus laying the foundation for problems in the future.

The discharge of stormwater into the nearest water course and on-site or off-site sanitation if applied properly, may represent an acceptable method of runoff and wastewater disposal in some urban areas with lower population densities. However, in large urban centres drainage by separate or combined sewers systems is recommended. Even so, in Africa, it will be economically non-feasible to cover the cost of combined systems as the sewers have to be extremely large to handle the expected combined flows. Also in order to serve all households, the gravity sewer network would have to be placed at considerable depths and at much higher cost. In most African urban centres, however, the issue of separate or combined sewers is more or less an academic exercise, because the existing networks, combined or separate are generally used for disposal of all kinds of urban wastes, particularly in the case of open channels. Metropolitan Lagos provides an interesting example for the issue of open or conduit/covered drains (Oyebande, 1990). The original network of roadside drains was constructed with concrete cover slabs with movable sections to facilitate maintenance. The drains were periodically flushed with public water supply and when flushing was sufficient, the covers would be removed and the drains cleaned manually as no mechanical equipment was available. In time, in the late 1970s and early 1980s the population and water demand growth outstripped the available water supply. Flushing of drains had to be discontinued in order to save badly needed water for domestic use. In order to reduce the drudgery of manual labour, the drain covers were removed permanently to facilitate the cleaning work.

Table 1.13: Stormwater Management Practices

Purpose	Method	Reason
Peak flow rate attenuation	Storm monitoring Detention/channel storage Gravel surfaces Rooftop/ parking lot storage Disconnected impervious areas	Flood prediction Flood routing Retardation Flood routing and lag Infiltration & attenuation
Runoff volume reduction	Retention storage Diversion Soakaways Basin recharge Infiltration French drains Swales Porous pavements Contour ploughing	Removal of flow Subtraction of flow Infiltration Increase in groundwater Flow reduction Seepage Flow retardation, Infiltration Infiltration
Provision for flooding	Insurance Flood zone building control regulation Flood warning	Compensation Limitation of damage Evacuation or diversion
Catastrophe aversion	Evacuation Sandbagging Emergency overflows Weir strengthening Water tanks	Structural failure High water levels Water flow control Dangerous flood levels Polluted water supplies
Erosion control	Berms Vegetation Rockfill Mulching Fertilizing Settling basins Sediment removal Screen Centrifuge Contour ploughing	Settling Stabilization, retardation Flow control Runoff control Stimulation of vegetation Catchment sediment Basin renewal Detritus Separation Surface storage
Pollution control	Street sweeping Street vacuuming Street flushing Catching first flush Refuse removal Storage Aeration Chemicals Comminuters Floatation Legislation Summons or fines Waste dump isolation Grass street verges Fertilization methods Land disposal	Catching solids Catching fines Total removal Most concentrated Avoidance of pollution Settling Biochemical oxidation Neutralization, precipitation Grinding large solids Scum, emulsion, oil Enforcement of standards Disincentive Runoff detention Catching fines, scums Minimization of washoff Removal of recoveries.

1.3 Treatment (Topic c)

Only 2% of cities in sub-Saharan Africa have sewage treatment, and only 30% of these are operating satisfactorily (UNESCO IHP 1996). The significance of wastewater treatment and disposal: that of protecting the public health and the environment seems not yet fully appreciated in the region. Much public education and creation of awareness is needed both for the decision makers and the public at large.

1.3.1 Large-scale technologies

1. Djibouti relies on the African Development Bank (ADB) to finance the sanitation master plan completed in 1988. It consists of construction of 8.3 km of main collector, a lift station, expansion of the treatment plant, and rehabilitation of the existing network. The treatment plant at Douda is designed for connecting 25,000 inhabitants, with possibility of extension to as many as 31,000 inhabitants. The treatment process is essentially an activated sludge process. The goal of the treatment is reduction of BOD_5 to 30 mg/l, destruction of pathogens to 99.9%, and elimination of solid particles larger than 100microns (World Bank, 1991).

2. South West Africa/Namibia is severely affected by water scarcity. Windhoek, the capital had a population of about 100,000 during a study which ended in 1984. Reclaimed wastewater was introduced in Windhoek in 1969 to overcome the effects of a serious water shortage as a result of prolonged drought. The water reclamation plant was established to augment the city's inadequate domestic water supply. The scheme was based on a clearly defined policy of total wastewater reclamation strategy and entailed three integrated lines of defence.

- Sewage catchment quality control is based on diversion of industrial discharges containing potential harmful chemical compounds from domestic sewage collection systems;
- Efficient reclamation technology backed by vigilant control: efficient removal of pathogenic micro-organisms, toxic metals and organic compounds, which may have detrimental effects.
- Vigilant surveillance of the final water produced: determination of its microbial and chemical quality and use of early warning systems, based on biological sensors such as fish.

The Reclamation Plant was commissioned in 1969. It was designed:
- to treat 4,500m^3/day
- to introduce an activated sludge plant at the Gammams Sewage Works
- for effluent low in ammonia-nitrogen.

The main stages of wastewater treatment are represented by settled sewage (99.7% virus positive, n=319), humus tank effluent or secondary sedimentation (93.7% positive, n=79) and maturation pond effluent (39.1%, n=156). This is followed by action of reclamation plant which performs breakpoint chlorination to produce the final water (0% virus, n=76). Then raw water intake from the dam is then received into the reclamation plant.

3. Harare, Zimbabwe: Harare has been described as unusual among cities of developing countries in the degree to which its sewage is treated (Porter et al., 1997). All Harare's five sewage treatment plants undertake primary treatment of the sewage, and at least half of the city's wastewater receives more advanced treatment. The product of the costly treatment is

water free of pathogenic bacteria, but too high in nitrates and phosphates. It is now been diverted to municipal farms for irrigation of pastures and crops. The city is known to have spent more on sewage treatment than on the sewerage reticulation system.

4. The wastewater treatment philosophy adopted in Botswana has been the least cost but technically affordable state-of-the-art waste stabilization ponds. Diminishing land now predisposes capital investments more into the conventional sewage treatment systems.

Sewer flow in Gaborone is 18,000 to 75,000 m^3 per day. It is deposited in stabilization ponds, covering 52 ha where treatment occurs through natural processes, with no machinery or energy input except for solar energy. As a result

- there is a reasonably high standard of treatment
- effluent is not fit for drinking, but some of it is used for irrigation, while some is further treated and discharged back into the Notwane River.

A switch is being made to sophisticated sewage treatment, in view of shortage of land for the lower-cost option currently in use.

5. The central sewerage system has been described earlier for Abuja, the new Federal capital of Nigeria. The temporary plant now in use has capacity to serve only 50,000 people, that is, 25% of its present population. It is therefore not able to provide adequate treatment of the wastewater. The Nigerian law on the quality of effluent from treatment plants requires BOD_5 of 20mg/l and suspended solids of 30mg/l, while coliform bacteria is reduced by 99%.

Extended aeration (activated sludge) is the method of treatment of wastewater from the Wupa drainage basin of Abuja city which serves 200,000 inhabitants. After the partial auto-oxidation of the wastewater, it is supposed to be oxygenated with diffused air mechanism and retained in the aeration tank for approximately 24 hours. But as noted earlier, because the capacity of the temporary treatment plant (contracts for the first of the five proposed treatment plants was awarded in 1989) is only 25% of the required size, aeration of the waste water could only be done for only a very short time. The result is a partially treated wastewater with BOD_5 of 30-40mg/l.

In many African cities some industries often locate outside the main industrial areas. In such cases, pretreatment requirements may be imposed; effluents produced by such industries may have to be pretreated in order to ensure compatibility with domestic wastewater before being treated together. In Abuja, such outliers are expected to comply with such requirements.

1.3.2 Small-scale and community-scale technologies

Aerated lagoon

In Lagos Island, an aerated lagoon was constructed in 1969 to treat night soil wastes. The site now known as the night soil treatment plant is currently being used by the local government as a fish pond. There is however a plan to rehabilitate it and re-convert it into a treatment plant.

Septic tanks

Table 1.14 presents a regional picture of the distribution of on-site sewage disposal technologies, including VIP toilets, in use.

Table 1.14: Access to onsite sanitation facilities in selected countries

Country/urban centre	% using septic tanks	% using VIP toilets	% using other pit latrines	% using public/shared toilets	% using pail/bucket systems	%without access to toilet facility
Botswana / Gaborone	34	-	52	14	-	-
Ethiopia /Addis Ababa	8	-	69[b]	42[a]	-	33
Ethiopia/all other towns (17 nos.)	3	-	49 [b]	37 [a]	-	48
Ghana/Accra (1990)	31	-	56[b]	41[a]	-	13
Malawi/all urban areas (1987)	10	-	65[c]	-	-	10
Nigeria/Lagos	60	30	3	-	0	2
South Africa	1.8	1.1	21.4	(1.6)	7.9	2.1
South Africa /North Cape	5.9	8.0	11.4	0.1	28.0	1.1
South Africa/ Western Cape	1.1	0.1	0	0.4	8.9	3.8
Zimbabwe	5	25	16	-	0	54
Zimbabwe/Harare Province	37	16	36	-	0	11

a = a portion of total population using pit toilets; b: this figure includes VIP toilets;
c= all types of latrines, including VIP and unimproved latrines.
Sources: World Bank(1989), World Bank(1997b).

Pit toilets

Composting latrine

The composting system is one of the alternative sanitation systems. Implicit to compost latrine technology is the notion of a dry (waterless) on-site system that accepts human excreta which gradually breaks down to produce a compost material that is safe for handling and disposal. It is recent in South Africa, having come into existence only since 1993. During the short period, its evaluation showed that Enviro Loo latrines performed adequately and were accepted by users as a satisfactory alternative to communal chemical toilets. Safety, privacy and accessibility are preferred aspects of the system (Scott, 1998). In particular:

- no adverse health impact was recorded among the users; and
- no sludge removal is required, though pumping out of storm water and grey water may be necessary.
- the technology as practised in South Africa acts more like a prolonged process of dehydration rather than a composting latrine. Further treatment of the waste material is therefore advocated by evaluation, once removed from the latrine container.

The most unfavourable aspect is that it does not flush!

Double-vault VIP latrine

Botswana's Ministry of Local Government and Lands, together with the Building Research Establishment in the UK has developed a double-vault ventilated pit latrine for use in squatter areas and site and service schemes. The VIP has been used in urban areas in Botswana since 1978. About 10,000 units have been built in Botswana since 1978.

It consists of a shallow pit divided into two vaults, each having an effective volume of $1.5m^3$. In stable soil, the pit is not lined. The covers are made of precast concrete and are removable. Emptying can be done manually or mechanically in a 3-4 year cycle. It is actually a cross between the double-vault compost latrine and the pit latrine. Like the compost latrine, it has the advantage of being permanent.

Reid's Odourless Earth Closet (ROEC)

ROEC is a type of improved pit latrine developed in South Africa and patented in 1944 (du McPherson, 1994). The pit is 1m x 2m and at least 3m deep. It is covered with a concrete slab fitted with a 75mm diameter vent pipe.

Concrete slab to keep out flies

Water and sanitation present serious problem in Mozambique. Only 12% of the dwellings in Mozambique are directly supplied with drinking water. Water is mainly supplied by public fountains. In urban environments, more than 70% of homes can obtain water from a communal network (public fountains), others rely on rivers, ponds, wells and tank trucks. A rigorous latrine construction campaign multiplied the number of latrines in Mozambique from 60,000 to 1.2 million. In 1984, 72% of urban dwellings were equipped, 93% in Maputo. Problems include instability of the soils, high water table, and the failure of the covers which were to keep out insects.

The squatting slab is the heart of any pit latrine, and the drophole is a very important feature of the squatting slab. It is therefore understandable that the government of Mozambique adopted a standard model of latrine cover obtained by research in place of the former wooden covers. It is 1.5 m in diameter and made of reinforced concrete, circular and slightly conical, and can easily be managed by one person. Its shape corresponds exactly to that of the pit and provides a better cover than a simple slab. The pit is raised up if the water table is high; it is built on breeze-block if the soil is unusually unstable. The local authorities through the Directorate of Construction and Town Planning of Maputo set up cooperatives in order to produce the model.

Members of the cooperative were elected by local authorities (the Facilitator Groups) affected. This coordinating committee (Inter-Cooperative Management Committee) carries out many functions that used to be performed by the government. Annual production of latrine covers was 18,000 in 1986, from cooperatives and workshops. Produced at a cost of Mt 500 (US$12), the present need is 2,500,000 in urban and peri-urban areas. The number of cooperatives and production centres continues to increase, and the project has been replicated in other towns with a total annual production of more than 10million (Brandberg, 1985).

The project is largely dependent on international aid[1]. It is also overly dependent upon support of government policy which could compromise its long term viability. The population must be more involved in the decisions to give the organizations greater autonomy.

[1] The contact institution is Mazingira Institute, P.O. Box 14550 Nairobi, Kenya.
Tel: 254-2-443219
Fax: 254-2-44 46 43.

1.4 Reuse (Topic d)

Wastewater and stormwater represent resources that are often not used, or only considered partly because of lack of information about their benefits. Fear of possible health risks, cultural bias, lack of a method to analyse the economics of reuse projects comprehensively account for this neglect. Negative experiences with wastewater reuse in areas where it is practised under uncontrolled conditions have also scared away many prospective adopters of reuse.

Wastewater reuse particularly in agriculture requires consideration of the health impact, agricultural productivity, economic feasibility and socio-cultural aspects, and is therefore a multidisciplinary project. The professionals might represent public health, sanitary, engineering, agronomy, irrigation engineering, finance and economics as well as behaviour sciences.

Agriculture is usually the principal water user in developing countries of the region (about 75-80% of total water use), followed by industry, consumer and domestic use. In several semi-arid areas of Africa water allocation is critical, and recycling of wastewater is a high priority not only for irrigated agriculture in peri-urban lands growing high-value crops, but even for the so-called lower-priority domestic and industrial use (as in Namibia). In these dry zones, wastewater may constitute 25-75% of available irrigation water. Examples include Angola, Namibia, Botswana, and Zimbabwe.

1.4.1 Djibouti

A sanitation master plan was completed in 1988 for Djibouti with the financial support of African Development Bank (ADB) (see Section 1.3.1). The plan involves construction of 8.3 km of main collector, a lift station, expansion of the treatment plant, and rehabilitation of the existing network. It includes plans for production of orchards and market gardening by using the products of treated wastewater for irrigation in a peri-urban farming area of 25 ha.

1.4.2 Wastewater reuse is advanced in Zimbabwe

Industrial wastewater is separated from domestic wastewater before the latter is treated. The Scandinavian Sponsor for Semi-arid Regions (water short regions) has been a keen sponsor of the water conservation project in a number of water short South African countries. The Ministries of Water Affairs and Forestry and Development in the respective countries and the water section of the regional organization, SADC based in Lesotho are the implementing agencies.

1.4.3 Reuse in South Africa and Tunisia

Table 1.15 shows the proportion of total sewage reused particularly for agricultural purposes in South Africa and Tunisia. As much as 75% was recycled in the arid environment of Tunis. There are few other reports of the cultivation of fish in sewage fed aquaculture in Africa.

Table 1.15: Reuse of wastewater in Africa

Country	Volume Reused Mm^3/yr	% of Total Sewage	Total Irrigation(%)	Remarks
South Africa (national)	70	16	-	1988
Tunisia (Urban Tunis)	68	75	-	1987

Source: Khouri et al. (1994)

1.4.4 Fish cultivation in sewage ponds in some African countries

Edwards (1992) reported on small scale operations in Kenya (Thika), Malawi (Dwangwa sugar estate), South Africa (Durban), and Zimbabwe. Fish, particularly tilapia is cultivated in sewage maturation and stabilization ponds. Reported fish yields are 4-5 tons/ha/growth period for the systems in Malawi, but only 0.8-1.2 tons/ha/year in Durban, South Africa.

1.4.5 Use of reclaimed wastewater in Namibia

South West Africa/Namibia is severely affected by water scarcity. Reclaimed water was introduced in Windhoek, the capital in 1969 to overcome the effects of a serious water shortage as a result of prolonged drought (see Section 1.3.1)

The percentage of reclaimed water in the blend with raw water sometimes was as much as 50% reclaimed water for short periods of less than 3 weeks during critical conditions. Average exposure to reclaimed water over the period of 17 years was 4.7% (i.e. some 292 days).

Since 1970s quality control studies have indicated that the product of the reclamation plant was of good quality and conformed to generally accepted drinking water criteria (Isaacson et al. 1987)

1.4.6 Effluent reuse as a supplement to water resources in Botswana

Average water demand for Gaborone by 2010 is estimated to be 63,000 m^3/day with a wastewater generation of 57,180 m^3/day. This represents a return factor to sewers of 90%, an optimistic estimate predicated on certain assumption concerning treatment technology, and perhaps climate, as the present ratio is of the order of 65% or less (Table 1.16).

Table 1.16: Botswana's wastewater resources

Town	Return flow in thousands m^3/day (estimated)	
	1990	2020
Gaborone	14.4	103
Francistown	5.0	38
Selebi Phikwe	4.4	21
Lobaste	3.2	8.2
Waneng	1.3	4.0

Source: UN DESD (1996)

These are resources that can be obtained within the borders of Botswana and at no extra cost to the government. In the light of erratic rainfall aggravated by long drought episodes (five years is not uncommon), it is prudent to maximize wastewater reuse. Established and possible uses of wastewater in Botswana include:

- Peri-urban farming around Gaborone to meet high demand by farmers;
- Demand by present and future industries;
- Demand for landscaping by Gaborone City Council
- Meeting water quality requirements for Water Utilities Corporation (WUC) for blending and treatment for potable use
- Provision of water demanded by the Ministry of Agriculture (MOA) for extensive agricultural research projects at Seble College.

1.4.7 Cape Town, South Africa

In Cape Town, South Africa, a variety of stakeholders have succeeded in integrating environmental concerns into larger planning exercises. In addressing the metropolitan spatial framework, a number of green and brown environmental issues, open space creation, resource use efficiency, and urban watershed management are also addressed at the same time. Win-win solutions such as recycling of organic wastes to provide compost for urban and peri-urban agriculture are found. Such agriculture typically provides a subsistence for a significant proportion of the city's food supply and jobs for the urban poor.

Except perhaps in Namibia and Zambia and South Africa, wastewater reuse is still in its infancy in Africa. The problems of accomplishing adequate treatment and cultural bias have militated against an effective use of this valuable resource, especially in the humid zones of the region.

1.5 Disposal (Topic e)

Only 5% of the inhabitants of Lagos Metropolis, Nigeria are connected to water-borne system and associated sewerage treatment plants. The plants do not treat the sewage to acceptable standards, and are poorly maintained and operated. Open storm water drains are common and in many cases act as open sewers, particularly for the conveyance of sullage water.

Most industrial wastewater was being discharged directly into water courses/bodies without any form of treatment. Major stormwater drains are not maintained. Both secondary and tertiary drains are also poorly maintained, hence they fail to alleviate flooding. The bulk of wastewater is being discharged directly and untreated into water courses or the Lagos Lagoon.

The Niger Delta is one of the world's largest wetlands, encompassing over 20,000km^2. The Niger Delta is relatively highly populated and urbanised, and has serious problems not only with industrial and oil pollution, but with inadequate domestic waste management. No municipal sewage treatment plants operate in the Niger Delta. Households, commercial establishments and industries discharge wastes directly into open drains. Many of the drains are unlined, blocked with solid wastes, or broken. Untreated urban wastewater is transported via sewage systems or drains emptying organic matter, including nutrients into receiving waters.

In Port Harcourt (the Niger Delta, Nigeria), dissolved oxygen levels in some rivers are very low and no longer able to support even herbivorous fish. High density areas of the city also have elevated levels of total solids, chloride and turbidity. Urban wastewater also contains industrial effluents, and household pesticides released into common drainage or sewerage systems. Water supplies are often degraded from the practice of laying water pipes in open drains or near soakaway pits, and constructing shallow wells near poorly maintained drains. Consequently, health risks associated with sewage contaminated water are highly significant and affect a large proportion of the urban population in the region, since there are no sewage treatment facilities. Plans are afoot to remedy the anomalous situation in this oil producing region.
The average wastewater flow for Lagos metropolis is only 115 l/c/d (compared to Cairo where it is 310 litres/day). In 1995 the total wastewater emptied into Lagos Lagoon was 811,300 m^3 per day, of which domestic wastewater accounted for 54%. The volume of wastewater generated is expected to increase to 1,663,090 m^3 per day by 2010 (Harrington, 1996).

1.6 Policy and institutional framework (Topic f)

The stability and sustainability of the water sector services, particularly wastewater and stormwater management, depend not only on the structure and the financial capability of the country, but also on the policy objectives and institutional framework. The institutions in place in the countries of the region reflect the diversity and complexity of the societies in which they operate. For instance while a federal structure decentralizes water and sanitation to the constituent units (states), as in Nigeria, many African countries still operate a unitary system of government, but the national water and sanitation agencies have provincial offices to which varying degree of power is delegated, as in eastern and south African countries. In many cases, the management of these services in urban areas is conceded to a national utility, parastatal, corporation, major municipalities or a private company jointly owned with the government. The latter is the case with SODECI in Cote d'Ivoire. This is one of the few countries that links sanitation or waste disposal with storm drainage. Examples of countries where municipalities are given responsibility for providing the water and sanitation services, and to a less extent, storm drainage, in urban areas include South Africa and Ethiopia.

1.6.1 Importance of management practice and autonomy

Many of the public and parastatal institutions are weak and in need of strengthening. These institutions are afflicted with poor management practices, overstaffing with poorly motivated and trained personnel, inadequate equipment and technical expertise as well as meagre financial resources, so the vicious circle continues.

A key factor of institutional capacity is the degree to which the service organization is financially autonomous and freed from the national budget. Authorities or agencies that derive the bulk of their revenues from user payments (e.g. water and sewerage fees, connection charges, special taxes), also possess the greatest stability (e.g. SONEDE in Tunisia, REGIDESO in the Democratic Republic of Congo (Kinshasa), SODECI in Cote d'Ivoire, the Water Supply Department in Nairobi, the Municipalities of South Africa and the transformed Water Corporations in Nigeria, particularly those of Lagos, Ogun, Kaduna States and Abuja Federal Capital Development Authority FCDA).

1.6.2 Political will and co-ordination of key organizations

Four countries of East Africa have had opportunities to appraise their policies and viability of their institutions in the light of government's political will to lead their countries in the path of sustainable management. The statements shown in Table 1.17 clearly indicate the policy framework and institutional reforms and capacity building they need to put in place. Even where political will abounds, political instability (due to war as in Liberia, Sierra Leone, Somalia, Mozambique, Congo-Kinshasa, Ethiopia, Eritrea, etc., or *coups d'état*) could be the most serious, immediate constraint on the improvement of these urban services in the region. Instability makes it difficult to plan ahead and to maintain implementation schedules. It also defeats efforts to build sustainable institutional capacity.

Table 1.17: Perceived policy and institutional capacity building needs in East African countries

Country	Priority/Needs	Remarks
Ethiopia	• sanitation policy – to be formulated • awareness building campaign and advocacy for improved sanitation • institutional capacity building – develop training programmes for urban and environmental sanitation (UES) • consistent community participation • feasible cost recovery mechanism and financial management linking O&M with income generating activities. • security of tenure	Waste water collection and disposal.
Uganda	• cost recovery • people participation • security of tenure in peri-urban settlements • establish policy guidelines for choice of appropriate technologies • catalyse individual and institutional capacity building. • develop national sanitation policy strategy, finalise white paper and develop operational guidelines	Waste management.
Kenya	• partnership and co-ordination of actors in the water sector • data gathering and analysis • dissemination of information • involve private sector in UES – framework for PSP	*focus on unplanned/informal settlements in Nairobi and Mombassa. *problem of excreta disposal.
Tanzania	Need for policy on: • appropriate technology options for on-site sanitation • appropriate design and provision of latrine accommodation • sludge emptying and treatment options • sewage management • mapping of waterlogged areas to provide information to reduce flooding & pollution • deregulation of exhauster services for on-site sanitation to involve PSP in latrine emptying and construction.	*water supply and waste management with special reference to reuse of wastes and reduction of groundwater pollution.

(World Bank 1997a)

The echoes from the East African countries went further to policy and institutional reforms particularly in the following areas:

- political will – government's commitment to addressing the problem of slums/informal settlement, and need for advocacy for favourable policy.
- in particular, that there is need for a policy on prevention of new informal settlements, along with a definite commitment for the improvement or relocation of existing ones, with resource allocation for user services;
- concerning the institutional set up, there is need for government to define the roles of institutions involved, and to put in place a mechanism for the coordination of key players. This is not peculiar to East Africa. Of the 43 African countries

surveyed in 1990 only 24 had a joint management of water supply and sanitation; some coordination mechanism is therefore necessary.

In Burkina Faso, progress in human waste disposal has been hampered by lack of a master plan and poor co-ordination between all stakeholders, with clearly defined responsibility for each agency. These same problems, as we have seen, affect many countries in the region.

1.6.3 Legal framework

It is through the legal instrument that institutional responsibilities discussed below are apportioned in the countries of the region. Some legislation is however very sketchy, uncoordinated and sometimes conflicting in some cases. In Nigeria, the Federal Environmental Protection Agency's (FEPA) "Guidelines and Standards for Pollution Control in Nigeria of 1991" represents the latest attempt to coordinate existing legislation and to provide a framework for enforcing safe management of wastewater and other wastes. Environmental standards that will make the guidelines more effective and meaningful are yet to be developed, just as is the case with Zambia. Many of the States in Nigeria (>30) also make laws to empower their Environmental Protection Agencies which represent FEPA's focal points in those states within the federal structure. The National Water Law of 1995 is however more far-reaching in its coverage, although its implementation is yet to be worked out.

Most of the existing laws on waste adopts a generalised approach with specific details left out. For instance, Botswana's 1962 Waterworks Act of 1962 empowered the officer in charge, usually the Minister, to make additional regulations to check misuse and pollution of water. In South Africa, the Water Act of 1956 administered by the Department of Water Affairs on behalf of the Minister, enables both quantity and quality of water to be controlled. For instance, it requires water to be returned to the river of source, a measure instituted to encourage water re-use and by implication, collection and treatment and disposal of wastewater. In Zambia, the Environmental Protection and Pollution Act of 1990 came into effect with the establishment of the National Environmental Council. It requires a permit to be obtained from the operator of a sewage system before trade or industrial effluent may be discharged into the system.

1.6.4 Institutions responsible for wastewater and stormwater management

In Zambia, the Ministry of Energy and Water Development is responsible for water resources planning and management in townships and rural areas. The Ministry of Local Government and Housing is responsible for urban water supply and sanitation through district councils, while the Ministry of Works and Supply – water supply and sanitation for institutions (army camps, ministries, schools) and sanitation (sewage treatment) for some district centres. The Ministry of Environment takes charge of establishing sewage treatment plant effluent standards and for environmental policies and pollution control. The task of coordinating these various stakeholders have called for much initiative and political will.

In Ethiopia, the Water Supply and Sewerage Authority (WSSA) carries out the implementation, operation and maintenance of urban and rural water supply and conventional piped sewerage. The Ministry of Urban Development and Housing (MUDH) handles the overall sanitation policy and planning and for providing technical advice to the urban authorities.

In Angola, after independence in 1975, the responsibility for water supply and sanitation devolved on the Department of Water Supply and Sanitation Services (DWSSS). DWSSS was one of the two departments of the former Ministry of Construction, but the city of Luanda has the National Water and Sanitation Company created for that purpose. In 1987, the water sector was transferred to the newly created Department of State for Housing, Urban Development and Water. This was again succeeded in 1991 by the Department of State for Energy and Water together with the establishment of the National Water Supply Board (NWSB) as central executive agency. To aid the Board are two new Departments of Water Resources Management and of Hydraulics. Such institutional instability together with the political instability is certain to affect the effectiveness of the organization, particularly in developing adequate capacity. This may explain the lack of qualified personnel which has hindered the NWSB's effectiveness.

1.7 Training (Topic g)

The overall manpower shortage of 27% in the water sector represents a shortage of 52% on the professional and technical post categories in Uganda, hence the call to catalyse individual and institutional capacity building (Table 1.17). There is shortage of qualified manpower, particularly in the professional and technician levels. It is very acute at local levels. In order to alleviate this problem, many persons have received training at professional, technical and artisan levels under government and donor-funded projects with training components.

In Angola, the Luanda provincial Water Company in 1992 had a total of 800 workers: 1.3% with higher education, 3.4% with average education and 95.3% with basic education (of which 66% were illiterate). The situation is more distressing in the other provincial companies which have only 2 highly educated technicians and 30 technicians with average education.

Ethiopia recognises the need for institutional capacity building to develop training programmes for urban and environmental sanitation (UES), and is advocating it, with the aid of donor agencies to supplement domestic resources (Table 1.17).

Some of the countries are trying to take advantages of available international, regional and national training courses of varying durations. Many of the countries of this region need to make concerted effort to alleviate this problem, by encouraging more persons to receive training at professional, technical and artisan levels under government and donor-funded projects with training components. Similarly as progress is made to involve the private sector in wastewater and stormwater management, engagement of the private sector should be used to provide for technology transfer and capacity building.

Another increasingly popular approach to training and manpower development is to adopt a regional approach by pooling resources together for training technical and managerial personnel in regional institutions. Such institutions receive the support of donors more easily than individual countries. Examples include a number of courses mounted by UNESCO and other international agencies, e.g. the professional postgraduate Diploma in Hydrology, University of Nairobi, Kenya. In other cases some water sector agencies collaborate with national tertiary institutions to offer relevant training programmes at middle level and/or professional level, e.g. in Nigeria (National Water Resources Institute, Kaduna) and Zimbabwe (Training Centre for Sanitation, Department of Civil Engineering, University of Zimbabwe.

1.8 Public education (Topic h)

Much public education and creation of awareness is needed both for the decision makers and the public at large in order to achieve sustainable wastewater and stormwater management, because the human elements can make the difference between success or failure in adapting technological innovations. It is vitally important to give public education on the health implications of sanitary disposal of wastes and stormwater, and the role that the people are required to play. For some time now, a number of African countries have tried to incorporate environmental education into the school curriculum in order to prepare their citizens for healthier lives in the next millennium.

In Uganda, only 50% of the established posts for extension staff is filled. The unfilled vacancies are due to poor conditions of service – basic salaries, fuel and other allowances for field work. As a result, necessary field surveys are not carried out, hence no hygiene and public education and follow-up support to bring about desired behaviour change.

The willingness-to-pay surveys conducted by consultants and NGOs in urban areas of many countries of Africa revealed that many urban householders were unaware that health and sanitation problems were often caused by their own poorly functioning and overflowing septic tanks. Jigui's Mobilisation and public education in Bamako, Mali (see Section 1.11.3) focuses on Cleanliness and sanitation.

In some countries the approach to public education is integrated for the water sector as a whole, including water saving, impact of wastewater collection and disposal. Some jingles are used on electronic media in public education. In Nigeria certain days of the week or month are fixed for sanitation activities.

School curricula are increasingly reflecting environmental education from primary to the university levels. UNESCO's initiative in this area has been introduced in a number of countries. Table 1.17 shows that some East African countries, particularly Ethiopia recognize the importance of education through awareness building campaigns and advocacy for improved sanitation. The World Bank's Participatory Hygiene and Sanitation Transformation (PHAST) accomplishes both public education and participatory action almost simultaneously in southern, eastern and to some extent western regions of Africa.

1.9 Financing (Topic i)

The new agenda for water and sanitation sector management is increasingly based consciously or unconsciously on an investment-tariff model which attempts a comprehensive analysis of demand for these services, particularly for urban areas. The analysis necessarily includes different investment scenarios – phasing of investments; analysis of affordability, willingness to pay the costs of services provided and how these affect the viability of different investment scenarios and the sustainability of the services provided.

1.9.1 Cost of water supply, wastewater and stormwater services

The average cost of water in Africa was $0.45/m^3 in 1990 while average water tariff was $0.46/m^3**.** The latter rose from $0.29 in 1985. Nevertheless average tariff exceeds average cost only in 42% of the countries in 1992 (from only in 22% in 1985). The cost of water is almost twice that in southeast Asia due to higher construction costs. Data from Ivory Coast, Uganda, Nigeria, Ghana and Kenya show that prices paid by the under-privileged in African cities to water vendors is 4-11 times that charged by public utilities in these same cities.

Table 1.18: Africa: Unit costs of construction of water supply and sanitation systems, in US$ per capita

	Urban Water Supply		Urban Sanitation System	
Year	House connection	Stand post	Sewer connection	Other means
1985	106	55	150	116
1990	91	55	120	100

Source: WHO (1992).

WHO's estimates of per capita cost of sewer connection shows that it decreased to US$120 in 1990 and for other options than sewerage system it was $100 (Table 1.18).

The figures (given per site) for South Africa (Table 1.19) is much less for both waterborne (including unsewered septic tanks) and other systems given in Table 1.18. Ironically the cost of the bucket system is higher (Table 1.19) than those of intermediate systems. The seeming anomalous situation is due to high recurring cost of doing the nuisance job of collection and emptying the excreta, and would also serve as a deterrent.

Table 1.19: Costs of human waste disposal per site, in South Africa

Average Costs	Capital (US$) per site			
	Waterborne	Loflos	VIP	Buckets
On site	190	207	259	103
Reticulation	241	-	-	-
Connector service	86	-	-	-
Treatment works	121	-	-	-
Total	638	207	259	103
O&M	US$/household/month			
On site maintenance	7.6	10.9	4.6	2.6
Water	22.4	1.6	-	-
Reticulation	13.8	-	-	-
Collection/Emptying	-	3.4	3.4	39.3
Connector service	2.6	-	-	-
Treatment works	5.7	1.7	1.7	4.3
Total	52.1	17.6	9.8	37.5
Total unit cost per household/ month	8.1	2.8	2.4	4.5

US$1=R5.8

For Namibia, the income and expenditure associated with the water supply alone shows that unit cost in 1991/92 was R0.89/m^3, while the unit income was R0.76/m^3. For sewerage, the shortfall is significantly higher.

In South Africa Central government expenditure on "sewerage and sanitation" (both current and capital) was 3.5% of social security and welfare expenditure and 1.5% of the general government expenditure. Expenditure on state water schemes and services was half of that spent on sewerage and sanitation largely because urban water supplies are essentially self-financing.

1.9.2 The constraints of governments and users

In many economies of the region, with the economic downtown which has been around for more than a decade, government subvention to the water sector has proved most inadequate even for operation and maintenance, not to mention capital for expansion of services to meet the needs of the exploding urban populations. For instance, in Ghana and Senegal, governments reneged on their commitments to, *inter alia*, increase tariffs and promptly pay bills of government and their parastatals. Botswana Water Utility Corporation (BWUC) charges commercially oriented tariffs; these tariffs were quickly adjusted in the past. Even in Botswana, problems have started to emerge as BWUC is finding it increasingly difficult to adjust its rates as required. There are obviously conflicting objectives that the government is tempted to pursue under this kind of arrangement which is short of giving full autonomy to the service agency.

The constraints which "tie" governments' hands include their political sensitivity to the issue of cost recovery, which is interpreted into higher tariffs and greater efficiency. The citizens have been told for so long that the utility services, particularly water, is their birth right to have free, being a social good. It has therefore become difficult for succeeding regimes to reverse the situation without incurring the wrath of the citizens. There is of course the stark reality that the governments of these poor economies cannot provide adequate subsidies to meet O&M as promised. The utility agencies are therefore unable to provide adequate services. As users become dissatisfied, they become unwilling to pay for substandard services, and the services deteriorate further. Thus goes on the vicious cycle of deterioration. But then there is also the problem that the costs of some technologies e.g. sewerage system are unaffordable by many beneficiaries. This has been the case particularly in many states of Nigeria, in Ghana, Namibia, and a host of others in the region.

1.9.3 African models of sustainable management

A number of African countries besides South Africa have a sustainable pricing policy in the water sector (water supply and wastewater disposal). For instance, in Malawi, water services are operated on a full cost recovery basis to meet O&M and capital formation. However, communal water points are heavily subsidized (MK 0.29/m^3). Between 1991 and 1994 the tariffs increased by 46-65% (Table 1.20). This is similar to the experience in Lagos, Nigeria, during the same period when water tariffs jumped from below O&M by upwards of 400%.

Table 1.20: Water tariff trends in Malawi, 1991-94

Increase in water tariffs (MK/per m^3)				
Quantity (m^3)	1991/92	1992/93	1993/94	% Increase
Up to 8	0.46	0.53	0.77	15.5
9-30	0.82	0.93	1.36	13.5
>30	1.90	2.25	3.05	15.5

With effect from April 1, 1993, consumers have been classified as individual, institutional and commercial/industrial user, and charged differently according to classification.

Cost recovery versus ability to pay (affordability) is a current and key issue in Africa. In some countries in the region, it is argued that sanitation services are expensive and should therefore be subsidized and a financing mechanism for intervention introduced. It is also emphasized that appropriate and affordable technology options should be considered and that resources should be mobilized through tariffs and recycling. Thus in South Africa, it has been decided that full water borne sanitation systems should only be installed where residents are able to afford the full maintenance and operation costs of the system. As discussed above, the level of perception of the new sustainability agenda is increasing, as obvious in the discussion of the cases of East African countries (Table 1.17), and the emerging consensus in the region is that technology options should be identified and criteria for determining the adequacy or appropriateness of technology developed.

The National Water Master Plan lists options for development of Botswana's water supply and sanitation to meet the water and sanitary requirements of all sectors of the community over a period of 30 years (1990-2020). The pricing policy is based on principles of equity and affordability. There is no government subsidy for urban areas, but those who use large quantities pay more to subsidize those who use less. Efficiency results in Botswana using less than 92 m^3 per capita per annum (252 litres/day). Table 1.21 presents a comparative picture of water tariff in Gaborone *vis-a-vis* those of two other African cities.

Table 1.21: Overall Water Consumption and charges

(a) Overall Water consumption	
Accra	86 l/c/d
Harare	257
Gaborone	174

(b) Water use		Water tariff (US$)		
		Accra	Harare	Gaborone
I	$10m^3$/mo	0.87	0.80	3.16
II	$50m^3$/mo	9.31	7.14	60.64
III	$100m^3$/mo	24.39	20.24	142.48

Source: (Poster et al. 1997).

In contrast to the situation in Botswana, there is no tariff policy for water and sanitation in Angola; the services are budget financed. The tariffs do not cover costs at all. In the provinces average tariff per m^3 is 15N.KZ ($0.75) and in Luanda it was until recently 20.N.K, i.e. $1.00. But it is now 200 N.KZ ($10.00). However, water tanker trucks by private companies sell water of doubtful quality for 50 N.KZ ($2.50) per m^3. The new approach or agenda in the water sector recognizes government's responsibilities as being largely one of a facilitator, and not that of actually delivering the services. These responsibilities include policy and strategy formulation, legislation, allocation of funds, grants and assistance, setting of minimum standards, the preparation of guidelines, monitoring and evaluation (Water Research Commission, 1995; Oyebande, 1996). The local government authority has responsibility of ensuring that everyone within its area of jurisdiction has access to water and sanitation services.

1.9.4 Private Sector Participation (PSP)

In many countries of Africa, the reality is dawning that mechanisms and guidelines for private sector participation (PSP) should be developed, particularly for wastewater collection and disposal. Who will invest and what are the returns and collection methods? Opportunities identified include taxing landlords and ploughing back such tax for the improvement of their informal settlements.

Some of the reasons given by wastewater and stormwater management services for the desire to involve the private sector include:

- enabling rapid expansion of areas of supply or service coverage;
- demand on available resources is too great;

- a desire, indeed urgent in most cases, to improve the level of service; the need to reduce cost of the service through increased efficiency; the need to find additional sources of funding.
- The delivery options (see also World Research Commission (1995) and Oyebande 1996) which are available for PSP have been outlined by the World Bank, and adapted to the African situation by South Africa in its preliminary guidelines for PSP (Water Research Commission 1995). The options range from service contracts, management of assets, rent of assets, to investment linked contracts and sale of assets. The following policy principles should guide such PSP to ensure optimum benefit to the public as well as the private sector company.
- Performance of the service providers must be monitored;
- The engagement of private sector should provide for technology transfer and capacity building;
- The service providers must be accountable to the people they serve;
- Provision of infrastructure must be done in a sustainable manner; and
- Opportunity should be given to all competent contractors to bid for the contract.

Table 1.22 shows some examples of private sector involvement in the water sector in Africa, and the level of such involvement.

Table 1.22: Examples of infrastructure privatization in Africa in the water sector

Management contract	Lease contract	Concession
Gabon	Central African Republic	-
Gambia	Cote d'Ivoire	-
Mali	Guinea	-
-	South Africa	-

1.10 Information sources

Abidjan, Cote dIvoire

- Dr. Mamadou Adama Sakho, Directeur de l'Eau, Ministry of Equipment – Hydraulics Department: E-mail: sakhoma@globeaccess.net

- Dr Sekou Toure, High Commissioner for Hydraulics, Office of the Prime Minister, Abidjan. Fax: 225-322192;

Accra, Ghana

Ing. Ebenezer Martey, Area Director, Ghana Water and Sewerage Corporation, ATMA, PO Box 1840, Accra. Fax: 663552

Addis Ababa, Ethiopia.

- United nations Economic Commission for Africa, Addis Ababa, Ethiopia.: Information on Water and Sanitation
- Dr. Stephen Donkor, Regional Advisor, Water Resources, Natural Resources Division ,UNECA, Addis Ababa
  Fax: 251-1-517200,). Email: donkore un.org

African Development Bank (ADB), Abidjan, Cote, d'Ivoire

Mr. Habte Sellassie- Manager, Division of Water and Sanitation (away on mission)
Mr. Kamoun Habib- Deputy Division Manager
Mr. Hospice D. Alves – Sanitary Engineer- Water and Sanitation
Mr. Wassel—Water Project, Nigeria etc.
The Librarian: Custodian of several relevant publication on the region's wastewater.

Botswana

- Mr. Baisi B. J. Khupe, Director of Water Affairs, PB 0029, Gaborone.
  Tel: 267-351601; Fax: 267-374372
- Mr. Boikanyo, Chief Executive, Water Utilities Corporation, PB 00276, Gaborone.
  Tel: 267-353467; Fax: 267-304676
- Mr. Kodise A. Selotlegeng, Senior. Public Health Engineer, Ministry of Local Government, PB 006, Gaborone. Tel: 267-354264; Fax: 267-352384.

Burkina Faso
Dr. S. R. Hien, Ministry of Health, Social Affairs and the Family of Burkina Faso, Directorate of Preventive Medicine, Ouagadougou.**SODECI- a Private Company** (Societe de distribution d'Eau de la Cote d'Ivoire:

- Essay Koudio, SODECI, Avenue Christiani, Abidjan O/BP 1843 CI
  Tel: 225-21 0623/212191.
- Director-General. Tel: 225-233005; Fax: 225-449412
- Director of Exploration. Tel: 225-233015
- Technical Director, Director of Sanitation. Tel:225-351706/358516
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Kenya
Mazingira Institute, P.O. Box 14550 Nairobi, Kenya. Tel.: 254-2-443219

Lesotho

- Mr. B. S. Goolam, Senior Engineer (Districts), Water and Sewerage Authority, PO Box 426, Maseru,
  Tel: 266-312449; Fax: 266-310006.
- Mr. Sechocha Makhoalibhe, Director, Department of Water Affairs, Ministry of Natural Resources, PO Box 772, Maseru.
  Tel: 266-317516; Fax: 266310437

Malawi

- Mr. Owen M. Kankhulungo, Chief Water Supply Officer, Ministry of Works, PO Box 390, Lilongwe 3. Tel: 265-780344; Fax:265-784678.

Mali

- Mr. Moussa Kaba, President of the GIE Jigui, BP 1502 Bamako (Mali) Tel.: 223-22-34-25; Fax: 223 23 1996.

Namibia

- Mr. Dudley Biggs, Director of Infrastructure, Ministry of Agriculture, Water and Rural Development, PB 13193, Windhoek. Tel: 264-61-3963069; Fax: 264-61-224512.

Nigeria

- Mr. J. A. Hanidu, Director, Water Supply and Control, federal Ministry of Water Resources and Rural Development, Abuja, Tel: 234-9-2343714;Fax: 234-9-234259
- Mr. O. Agada, Sanitary Engineer (Sewerage), FMWRR, Abuja. Tel:234-9-2343733; Fax: 234-9-234259.
- Mr. JWE Metibaiye, World Bank, Abuja. Tel: 234-9-234269-74.
- Dr. J. Adewoye, Director General, Federal Environmental protection Agency, Abuja. Tel: 234-9-2345809.

South Africa
Department of Water Affairs and Forestry(DWAF), Pretoria, South Africa.:
Address: Bag X 313, Pretoria 0001, South Africa. Fax: 27-12-328 6397;

- Director of Water Resources –Mr. Nichols J. Van R. Rabie
- Director of Water Services Planning --Mr. Fred Van Zyl
- Chief Director, Scientific Services: Mr. Tami Sokutu (Eml: kaa@dwaf-pta.pwv.gov.za)
- Mr. M. Sorrious. Manele
- Director of Water Quality management- Mr. JLJ Van der Westhuizen
- Mr. Boniface Aleobua (Eml: wad@dwaf.pwv.gov.za).

South African Water Research Commission (WRC);
Fax: 27-12-3312565.

- Dr Jayant N. Bhagwan, Research Manager, Water and Sanitation (Eml:bhagwan@wrc.org.za)
- Mr. Hugo Maaren, Research Manager, Hydrology (Eml: hugo@wrc.org.za)
- Librarian, Water Research Commission, Pretoria.

Swaziland

- Mr. Stephen S. Dlamini, Water Control Officer, Ministry of Natural Resources and Energy, PO Box 57, Mbabane, Tel: 268-42321 Ext. 166; Fax: 268-42436.

Tanzania

- Mr. Arthur R. Mutalemwa, Director General, National Urban Water Authority, PO Box 1573, Dar es Salaam. Tel: 255-51-311914.
- Mr. A.A. Senguo, Director, Planning, Ministry of Water, Energy and Mineral, PO Box 9153, Dar es Salaam. Tel: 255-51-31433-5.

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- Mr. Matungulu Kande (from Democratic Republic of the Congo), UNEP
- Dr. Emmanuel Naah, Regional Hydrologist, UNESCO (Fax/Tel: 254-2-622351; Eml: Naah@unesco.org.

World Bank Regional Offices.

Regional Office of the World Bank in Nairobi, Kenya.
High Park Building, Upper Hill Road, Nairobi, Kenya; Fax/Tel: 254-2-260300, 260400, 714141/704030.

- Prof Ladipo Adamolekun, Principal Public management Specialist
- The Librarians (Ground floor and Third Floor Libraries).

Regional Mission of the World Bank in West Africa.
BP 1850, Cocody, Abidjan 01, Cote d'Ivoire. Tel.: 225-442227; Fax:225-441687.

- M. Mathys, Director GREAO

Zambia

- Mr. Andrew Mondoka, Secretary, The Water Development Board, Dept. of Water Affairs, Ministry of Energy and Water Development, PO Box 50288, Lusaka. Tel: 260-251-525; Fax: 260-1-250721

Zimbabwe

- Mr. Phillimen Chedondo. Provincial Water Engineer, Department of Water Development, Ministry of Lands, Agriculture and Water Development. PO Box 554, Gweru. Tel: 2632511; Fax:263-54-52158
- Dr. Thomas Chiramba. Director of Works, Kwekwe Municipality, PO Box 689, Kwekwe. Tel: 263-2301-7; Fax: 263-4301.
- Mr. Paul Taylor, Director, Training Centre for Water and Sanitation, Department of Civil Engineering, University of Zimbabwe, Box MP 167, Mount Pleasant, Harare. Tel: 263-4-303211.

1.11 Case studies (Topic k)

1.11.1 Djibouti's sewerage system

The sanitation situation in the city state of Djibouti is unique in Africa. It may not be a best practice example, but is a good one; the problem in showing it off being the incomparably small scale of its operation. There is no doubt, however that it demonstrates the principle and it's feasibility where population can be kept under control. The city of Djibouti which houses some 83% of the country's population is served by 24.4 km of sewers. The system includes 12 lift stations (because of very flat land surface) and a sewage treatment plant based on the activated sludge process at Douda. The constraints of its wastewater management include near-zero altitude which limits discharge into the sea at low tides. Even this tiny country has problem of covering its high density, low income housing areas where water supply is also inadequate. The country relies on African Development Bank (ADB) to finance the sanitation master plan completed in 1988 (World Bank, 1991). The master plan consists of construction of 8.3 km of main collector, a lift station, expansion of the treatment plant, and rehabilitation of the existing network.

1.11.2 Ouagadougou: community based water sector development[2]

The population of Ouagadougou could reach 1.4 million by 2000. Ouagadougou consists of 30 sectors. A local Fund gathered loans to finance systems of barrels and carts set up to transport water from standing pipes to houses. More than 30 barrels and carts were distributed. This was an emergency measure to solve the problem of acute water shortage and of disposing of wastes in a sanitary manner. The National Office for Water Supply and Sanitation (ONEA) connected 14 schools to the city supply network. Parent-Teacher's Association is responsible for part of the costs.

In 1989 sociologists conducted a socio-sanitary survey. They interviewed families and completed questionnaires. They involved the public and their opinion with all phases of development, through health committees and sector committees, mayors, community,

[2] The contact person is Dr. S.R. Hien, Ministry of Health, Social Affairs and the Family of Burkina Faso, Directorate of Preventive Medicine, Ouagadougou.

organization and those in charge of sub-sectors. The project was conceived and led by people of national standing.

Double ventilated pit latrines (DVIP) were installed in public areas (schools, and free health clinics) and incinerators were set up to handle solid wastes. The sanitary engineering service of the Education Directorate for Health and Sanitation ensures the technical supervision of the activities. The Project also trained local artisans to transfer technologies to the communities that request them. The measures were low-level activities, but were hope inspiring as it was community based.

1.11.3 Jigui's Mobilisation and public education in Bamako, Mali[3]

Hamdallaye District of Bamako is an extended area with 40,000 persons (6,500 households) which had little sanitary infrastructure. A survey conducted by an economic interest group Jigui identified the existence of unauthorized garbage dumps and the discharge of waste water in the streets. Jigui worked towards developing a garbage-collection system, hygiene education, and involving the population in sanitary projects. It also initiated, supervised and executed activities with the people. District authorities and technical Services provided active assistance (such as final waste disposal) and technical advice (on cesspools and institutional arrangements). The French Development Bank finances aspects of the project dealing with waste, other aspects are funded by African Development Bank and Infrastructure Fund of the UN.

The two major areas of focus are:
(a) Operation `Bseya' or "Cleanliness" – There is daily garbage collection for all concessions of the district that subscribe. Garbage is deposited in intermediate points (at CFA 750 per concession per month cost of service): garbage cans provided are emptied daily, into tipping donkeys carts.
(b) Sanitation – Jigui[4] plannned installation of individual cesspits in the concessions to receive wastewater previously discharged into the street (World Bank 1996). Enthusiasm is propelled by debates in the concessions, weekly meetings, and by committees of elders.

1.11.4 DANIDA's Kenya Sewerage House Connection Project

Forty centres were identified by the Danish International Development Agency (DANIDA, 1989) in Kenya to qualify for water borne sewerage systems, and approximate 30 sewerage systems have since been constructed all over Kenya, at a cost of DDK 38.9 million (Ksh 51.2 m). The work was partly financed through foreign donor funds and partly through Government of Kenya (GOK) funds allocated to Ministry of Local government (MOLG) and Ministry of Water Development (MOWD). The main donors in the sewerage sector have been AFDF, KFW, NORDA & DANIDA (DANIDA, 1989).

<u>Commissioned DANIDA projects:</u>
Isiolo – June 1983 (13 % completion)
Busia – September 1983 (38% completion)
Homa Bay – July 1985 - 47% of total costs by DANIDA (33% completion)
Nyahururu – May 1986 - 53% by local loans from local governments, etc. (99% completion)

[3] The contact person is Essay Koudio, SODECI, avenue Christiani, Abidjan O/BP 1843 CI
Tel: 225-21 0623/212191.

[4] The contact person is Moussa Kaba, President of the GIE Jigui, BP 1502 Bamako (Mali)
Tel.: 223-22-34-25; Fax: 223 23 1996.

House connections phase was entered into in 1986 to increase the number of beneficiaries from the sewerage schemes in the 4 towns from 18,900 (April 1985) to 43,800 (end of project) at DKK 23.4 million. Much progress had been made in installation of sewer pipes and house connections progress by February 1989.

Sewerage charges-based on volume of water consumed in the 4 towns: (25% of water meters were out of order) so only estimates are used based on previous consumption, Ksh 12/month. No charge for consumption in excess of 9 m^3/month, but more or less a flat rate, which is a regressive action. The costs of the projects are: Busia 26.7 K Sh million, Homa Bay 2.3 K Sh million, Isiolo 18.83 K Sh million, and Nyahururu 43.23 K Sh million. The charges for water supply and sewerage services reflect clearly the underlying principle of cost recovery.

Table 1.23: DANIDA Sewerage Project

(a) Water Supply:

Water Supply	Busia	Homa	Isiolo	Nyahururu
Connection fee	287/50	-	-	750/- (domestic)
Weekly meter rental	3/50	3/50	3/50	10/-
Monthly tariff per m^3	2/50	2/65	2/-	(a) Min. 30/- up to 6m^3 (b) 6-10m^3 : 3/- per m^3 (c) >10m^3: 4/- per m^3
Minimum Charge per month	21/50	21/50	21/50	30/-

(b) Sewerage

Sewerage	Busia	Homa	Isiolo	Nyahunm
Sewer connection fee	500/-	1000/-	Res. 400/- Com.500/- Ind 800/-	750/- 1500/- 2000/-
Monthly sewer rate per m^3	3/-	1/20	2/-	Up to 6m^3 – 20/- Additional 2/- per m^3
Monthly min. charge	15/-	11/-	12/-	20/-
Sewer unblocking fee	-	-	180/-	-
Emptying tank per load	750/- +50/-per km.	-	250/-	-

Res. = Residential; Com. = commercial; ind. =I ndustrial

Source: DANIDA (1989)

Water tariffs and charges are set by Federal Government in respect of water undertaking. Sewerage tariffs and charges are approved by the Ministry of Local Government (MOLG) annually.

1.11.5 KWAHO in Kibera, Nairobi

Kibera, Nairobi's largest peri-urban settlement has a population 470,000. Kibera slums represent 25% of Nairobi's population, and are located on a land area of 110 ha. Population density at Kibera is 2300/ha

The water supply situation is not too bad as there are 800 water points with public and private access. Population per water point varies from 291 in Laini Saba to 743-790 in Kianda, Silanga and Makina. Sanitation is however pathetic: there are only 2800 toilets for the whole of the 200 ha slum area. i.e. 170 persons per toilet; it is 257 and 330 per toilet in Kianda and Soweto respectively. Moreover, most of these toilets are not always in good condition. Drainage is virtually non-existent. During the rains April/May and December, the areas can hardly be traversed on foot and storm water and sullage is of particular nuisance.

The Kenya Water for Health Organization (KWAHO) helped poor residents of Nairobi in formal settlement to establish a latrine emptying service for which they were willing to pay in advance (KWAHO, 1992).

With KWAHO's help, the residents built VIP latrines and needed a way to dispose of the resulting waste. The Norwegian Agency for Development Cooperation (NIRDA) provided support for a special suction truck able to maneuver its way through the narrow streets and empty the pit latrines regularly. A 13-member community management team oversees the operation. More than 6,000 households paid the US $9 advance fee to have their home latrines emptied.

1.11.6 The strategic approach in Ouagadougou

Ouagadougou (Burkina Faso) wastewater plan[5] used the strategic approach.
The choice of technologies depends on:

- Settlement type
- Preference of users
- Existing installations
- Water service/use level
- Natural conditions, e.g. geology & soil, hydrology
- Construction and maintenance costs & affordability

Pilot project was launched to evaluate technology options: VIP/ Manual flushing latrines, septic tanks with soakaway trenches, block of public latrines, wash tubs and sumps for household wastewater; rehabilitation of existing installations.

The Private sector carries out the construction and maintenance. The National Water and Sanitation Office (ONEA) of Burkina Faso is normally in charge of planning for Ouagadougou.

Lessons learnt from the project indicate that sustainability can only be assured if responsibilities are truly shared among that three tiers or foci: the community, private sector and the public sector

1.11.7 Kumasi: The strategic approach to waste and wastewater management

Since 1991, the Kumasi sanitation project in Ghana has applied the strategic approach to develop strategy for urban sanitation in Kumasi of 770,000 people in which 75% lack adequate sanitation services. With the assistance from UNDP-World Bank Water and Sanitation Program in Abidjan; the Kumasi Metropolitan Assembly adopted a demand – driven approach based on user preferences and willingness to pay, short planning horizon (10-15 years) and breaking of the overall plan into projects that can be implemented separately but incrementally providing total coverage.

[5] Contact information: M. Mathys, director GREAO, Regional mission of the World Bank in West Africa. BP 1850, Abidjan +01, Cote d'Ivoire. Tel.: 225-442227; Fax: ...441687

A survey of willingness to pay for improved sanitation services was very positive.

- The poorest people who used public latrines were paying more for sanitation than those with household systems and so were willing to pay more to have improved home sanitation.
- The $28 million sanitation plan (1991-2000) includes $15 million for home latrines (10% financed by users), $9 million for sewers in tenement areas (no user finance), $3 million for schools and public facilities and & $1 million for support to the Waste Management Department Unit. Unit costs are $31 per capita in the lower density housing area (population of 470,000) and $53 per capita in the tenement housing area (population of 170,000). Public latrines are to be under private sector management franchises.

In contrast to the strategic approach, past approaches to urban sanitation have usually been based on city wide, donor financed high projects that attempt to address all the problems at once with little recognition of true priorities or user demands.

The status of wastewater and stormwater management in the region is certainly far from satisfactory. A few countries have caught the vision of the need for strategic approach to water and sanitation services by providing services that are demand driven, participatory and affordable, while the goal of cost recovery is kept in sharp focus. This trend is emerging because the government could not live to its promise of providing adequate subvention to enable the sector agencies provide adequate coverage and level of service. Nevertheless a large number of governments of these poor developing economies still fail to demonstrate political will to play the role of facilitator and minimizing disrupting intervention in tariff and other decisions that are vital for sustainability of the services.

The acute shortage of funding for clearing the backlog and expanding the services as urban population continues to explode, has also led some countries to develop strategies for tapping the private sector‘s resources. In countries where a form of privatization in either form of service or management contracts have been adopted, much more efficient and adequate services are being provided. It has been shown in many studies that the people in this region, including the low-income class are willing to pay higher tariff for improved services in the water sector. But while people of Botswana may be paying less than 7% of their income on water and sanitation services, full waterborne sanitation services in particular are not affordable in many African countries. Such services may exceed 60% of the income of many prospective users. There is therefore a need to carry out proper rapid assessment to determine appropriate wastewater disposal technology.

In sub-Saharan Africa, where availability of water in adequate quantity cannot be taken for granted, and where settlement pattern and accessibility and internal services (pedestal with flush mechanism, toilet structure, on-site sewer connection and internal reticulation) are often not suited to the desired waste disposal and management technology, much flexibility must be applied. These internal services may raise housing value by up to 20% or more (as in Gaborone) and be unaffordable for a number of low-income people. There is no doubt that a comprehensive approach to wastewater and stormwater management is indispensable for sustainable management. It should include considerations of aspects of water supply, housing type and infrastuctures, solid waste disposal, and the proportion of users' income going to the various service.

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2. Asia (West)

2.0 Introduction

Most of the countries of the western Asia region lie in the arid to semi arid zones and are considered as countries with scarce water resources. With few exceptions, the per capita share of water for all purposes are less than 1000 m^3/capita/year which drops to less than 200 in some countries. Associated with that is the predominant dry and desert ecology which has a profound impact on water consumption, human settlement and socio-economic development of the region. This, of course, will have a significant effect on the volume of per capita production of wastewater and its physical, chemical and biological characteristics.

In terms of their approach to wastewater and stormwater management, it is useful to characterize these countries with respect to their socio-economical development and standard of living. They range from oil producing countries which enjoy growth and prosperity to poor countries; some of them being among the least developed countries. In spite of that, most countries share common problems such as high population growth, rapid urbanization and severe water shortages.

In view of the above and based on their health status and their water supply and sanitation services, the countries of this region can be classified under three groups. Group 1 includes Egypt, Syria, Iraq, Yemen and the Palestinian territories; Group 2 includes Jordan, Oman and Bahrain; and Group 3 includes Saudi Arabia, Kuwait, Qatar and United Arab Emirates (UAE). This classification is based mainly on sanitation services provided to their communities and the level of treatment facilities. It coincides also with standards of living and Gross National Product (GNP). The latter affects to a high degree planning and management of wastewater collection and treatment.

In the last 30 years, the region has witnessed a rapid urbanization with unprecedented growth in their cities due to high rate of population growth and the large-scale migration form rural to urban areas. The population pressure has put a severe load on city services and has stretched city resources to a limit where they could not adequately respond to demands. As a result city authorities were unable to provide the necessary infra-structure and basic services specially for secondary cities. Their priority has been basically in providing residences with water supply whereas the provision of sewage and stormwater scheme has been given second priority. The exception, of course, are the very rich oil producing countries.

2.1 Wastewater characteristics (Topic a)

The characteristics and volume of wastewater in West Asia countries depends upon the water supply coverage, availability and cost. Due to the shortage of water, the volume of wastewater produced per person is smaller than that produced in the European countries. Water consumption for most of the West Asia is low and it is estimated to be around 100 liters per person per day. As a result the concentration of the physical, chemical, and biological consistuents will be higher, in cases where sewer systems are available. In rural and poor areas the situation is completely different. The availability of minimum sanitation facilities and very low water consumption rate coupled with the lack of collection system affect to a great extent the wastewater characteristics. The degree of urbanization and industrialization and the disposal of industrial and stormwater to domestic sewer network will also affect the characteristics of wastewater.

Wastewater production and characteristics vary from country to country, from rural to urban areas and from city to city. The coverage of sanitation facilities and sewage networks is greater in oil producing countries; and greater still in major cities compared with secondary cities and rural areas. In urban areas, the sanitation services cover more than 85% of the houses while in rural area the coverage is only about 25% (Table 2.1).

Table 2.1: The population of West Asia countries, percent of urban population, percent of population connected to sewer systems, domestic and industrial water supply, and volume of wastewater produced and portion used in irrigation

Country	Population (in million)	% Urban population	% population sewered	Domestic water supply MCM	Industrial water supply MCM	Treated wastewater MCM	Used in agriculture MCM
Bahrain	0.570	91.0	65	102.3	10.0	50	14
Egypt	63.271	45.0	52	3315.0	4600	900	280
Iran	61.975	59.6	10	4395.0	1215	300	200
Iraq	20.604	75.2	50	1400	2100	-	-
Jordan	4.356	72.1	54	230.0	36.0	70	70
Kuwait	1.687	97.3	90	216.0	15.0	110	55
Lebanon	3.084	87.7	52	368.0	50.0	6.0	3.0
Oman	2.302	38.6	20	75.0	22.0	30	28
Qatar	0.558	91.8	70	71.0	9.0	25	25
Saudi Arabia	18.836	80.7	72	1617	200.0	550	230
Syria	14.574	52.8	55	620.0	280.0	400	400
UAE	2.260	84.5	85	515.0	200.0	110	110
Yemen	15.678	34.6	35	221.0	32.0	30	8.0
West bank	NA	NA	35	NA	NA	20	NA

MCM = million cubic meter

The organic, solids and nutrients loading of the wastewater in the West Asia region vary from country to country and vary also according to location within the country and with time. Table 2 shows typical wastewater characteristics in some selected countries of the region. The 5-day biological oxygen demand (BOD_5) ranges from 280 to 570 mg/L with an average of 530mg/L; total suspended solids (TSS) ranges from 300 to 700 mg/L with an average of 453 mg/L; the ammonia – nitrogen (NH_4- N) ranges from 45 to 110 with an average value of 75 mg/L. These values are very high when compared with the average US concentrations. It can be noted that a significant portion of the salinity loading in the wastewater is associated with the background salinity in the water supply.

The high concentration of these pollutants characterize the sewage of high strength wastewater which are typical of areas in which water use rates are moderately low. Dividing the observed wastewater concentration by the per capita water consumption rate (which is around 100 lpcd) gives typical loading for organic, solids and nutrient composition of wastewater (Table 2.2).

In some locations (poor urban areas and refugee camps), the concentration of pollutants is very high where TSS exceeds 3000 mg/L. The situation is also different in areas that are not connected to the public sewage network or in rural areas. Most of them use on-site sanitation technologies such as pit latrines, pour flush toilets and septic tanks. The septic tank is the most common method where a sealed concrete chamber receives all household wastewater.

Table 2.2: Wastewater characteristics and per capita loading of most countries in the West Asia region

Parameter	Unit	Avg.	Range	US Avg.	Water consumption (Lpcd)	Per capita Loading g/c-d
BOD_5	mg/L	530	280-750	192	100	53
TSS	mg/L	453	300-700	181	100	45.3
NH_4-N	mg/L	75	45-110	13	100	7.5
Total N	mg/L	100	80-120	34	100	10
Total P	mg/L	15	10-20	9.4	100	1.5
TDS	mg/L	1000	620-1300	-	100	100
Cl	mg/L	260	125-350	-	100	26
Na	mg/L	180	95-240	-	100	18
S	mg/L	70	12-115	-	100	7
Br	mg/L	0.43	0.15-0.6	-	100	0.04

Special tanker trucks are available to empty and dispose the sludge to wastewater treatment facilities or receiving points.

In practice these septic tanks are not completely sealed allowing more infiltration into the ground, which produce a very high strength wastewater. The black water that is disposed of in latrines is all allowed to decompose in the pits. Usually, when these pits are filled, they are sealed and enclosed and new pits will be dug.

Non sewered areas of Jordan, Lebanon, Syria, the Gulf States and partly Egypt and Iraq use septic tanks or cesspool. The main risk in their use is the seepage to groundwater, specially if the water table is shallow or these pools are excavated in limestone formation.

The disposal of industrial wastewater to the public wastewater network is very limited for two reasons. First; many countries like Jordan, Saudi Arabia, Egypt, and UAE do not allow industries to dispose their wastes to public wastewater network unless they comply with certain standards and must be compatible with the sewage treatment system. Second, most of the West Asia countries are considered non-industrialized countries with the exception of Egypt, Iran, and Iraq. In addition, most of their industries are light and concentrating on food processing, dairy products and soft drinks. Other industries that produce material wastes such as paper, steel, cement, paint, chemical, fertilizers, and plastic are not allowed to discharge their waste to the municipal sewer. Instead they must have their own treatment plants and recycle or reuse their wastewater on-site. Hazardous industries are encouraged to treat and dispose their wastewater through evaporation, drying and incineration. In some industrial areas near Amman (Jordan) and Damascus (Syria) and Cairo (Egypt), the high concentration of TDS, COD, and BOD are the result of a much higher fraction of industrial waste that are allowed to be discharged in the waste stream. In Jordan, Saudi Arabia, Egypt, and UAE the dairy processing and paper industry treat their wastewater on-site and recycle the effluent or reuse it for agriculture.

In many countries, e.g. Egypt, Jordan, Saudi Arabia, Syria, and UAE, the new planning policy is to confine industry to what is called industrial cities. These cities are equipped with sewer pipeline networks and treatment facilities. Depending on the type of effluent of each industry, a pre-treatment facility is recommended.

Not all major cities in the southern part of the region are equipped with stormwater drainage systems because of rare rainfall events. One or two rainfall events in Cairo do not justify construction of stormwater sewer networks. Only some major and coastal cities in the region are provided with these networks. Where such facilities exist they are separated from the wastewater sewer system except Tehran (Iran) where both networks are connected. The Jordanian legislation does not allow stormwater connection to the main sewer network.

2.2 Collection and transfer (Topic b)

The percentages of people that are connected to the public collection systems in West Asia region based on 1997 data are presented in Table 2.1. In some countries like Iran, Yemen, Oman, and the West Bank, only 10-30 % of the population is connected to the public collection systems. The percentage of population that is connected to public collection system in the oil producing countries (Saudi Arabia, Bahrain, Qatar, Kuwait and UAE) ranges from 70-90%. About 50% of population of the remaining countries (Syria, Egypt, Jordan, and Iraq) are connected to public networks. The other collection system is septic tank or cesspools. People in the rural areas and in the countryside use other facilities such as latrine pit or small-bore sewer, which dispose their waste into the ground. In some cases septic tanks are associated with field drains.

The transfer of wastewater is always associated with public connection systems or conventional sewage system. Public authorities manage these kinds of systems. In almost all West Asia countries, there are no specific national standards for sewer design. The European and American design standards are mostly being used. As a result of inadequate development of the wastewater engineering discipline an ad hoc mix of technologies are used in the region. Usually wastewater flows into sewer by gravity through different levels of sewer lines with manholes and inspection stands. Where topography permits, the flow to the main sewer is by gravity; otherwise wastewater will be discharged into the pipeline under pressure by a number of pumps.

In Jordan, the collection system consists of sewer pipeline networks that collect the domestic wastewater from individual household, business, and industrial connections. The existing policy is that the storm drains should not to be connected to the sanitary sewer lines. However, in the greater Amman area, about one quarter of the buildings have storm drain connections to the sanitary lines. Consequently manholes surcharge and raw sewage outflows in the streets and basements of buildings during flood rainfall events. The overall hydraulic capacity of greater Amman collection sewer system is adequate to carry the wastewater flows for which it was designed. However, problems revealed by the hydraulic analysis are silt/debris build up and stormwater inflow. For example, field investigation revealed about 10% of all manholes inspected and 25% of all pipes inspected contained significant debris build up. The impact of roof drain connections is significant which will increase the amount of surcharged pipes during wet weather. The impact of stormwater inflow is pertinent for the major conveyance system, which is already at full capacity with dry weather flow.

In areas where septic tanks are used, the policy is to collect and discharge sludge at septage receiving stations. Septage that is collected by tanker trucks are taken directly to the treatment facilities or septage receiving points. This policy includes additional cost of the septage to the receiving points. However, the private users pay the cost of trucking septage. The percentage of septage water to the total wastewater influent to the treatment plant is in the order of 5-10 %. The difference, which is 30-35%, is either lost from the cesspools through seepage or being discharged into dump sites or wadis (dry streams) in close proximity of the source of septage. In areas where treatment facilities are not in the proximity or close-by, the septage of the cesspools are discharged into leach fields which are associated with solid waste disposal sites (dump sites). Examples of that can be seen in most villages and secondary cities of Jordan, Yemen, and in Egypt to wadis. About 15-20% of the septage is discharged to sewer or treatment facilities. In some countries, like Oman, septage should be pre treated before mixing with collected domestic wastewater but there are no such regulations in other countries. The pretreatment facilities are in the form of settling tanks.

For industrial wastewater, the current regulations, in almost all countries, require that industrial and commercial wastewater effluent discharged into the sanitary sewer system should be protected. Implication of these regulations will include establishment for pre-treatment standards and construction of pre-treatment facilities. The construction of the treatment facilities will require additional financial funding.

In Jordan all branches and sub-mains are made of concrete pipes whereas pressure pipelines, siphon pipelines, and force mains are made of steel. In Kuwait, Saudi Arabia, and UAE, sewer lines are made exclusively of asbestos cement pipes ranging from 8 to 48 inches in diameters. The mains are receiving sewage from branches and sub-mains and conveying wastewater to main pumping station by means of gravity or lifting stations or screw conveyors. In cities like Amman, where mountains and valleys are the main features, a siphon pipeline and tunnels are used in sections of the mainline.

In areas that are not connected to water supply systems, such as: remote areas and undeveloped town areas, the volume of water consumption is very little. In these areas, pit latrines are used and greywater is disposed into the streets where it forms clogged areas or it evaporates. These spots can be found in the very poor undeveloped parts of major cities or in some of the refugees' camps in Jordan or Lebanon. In some rural areas of Yemen, Egypt, Syria and Iran dry latrines are used and water for other household use are limited resulting in minimum wastewater disposal.

There is a major concern for wastewater collection and transfer for a large number of holdings and housing complexes that are increasing near remote coastal areas or near archeological sites. The efforts in Jordan and Egypt are to have special collection and conveyance systems or to have for each holding a small scale treatment plant. The newly developed tourist areas have to be equipped with on site treatment facilities coupled with reuse systems.

2.3 Treatment (Topic c)

In the West Asia region, a diverse range of technologies are used in various countries ranging from conventional wastewater treatment methods and wastewater stabilization ponds in large communities to small-scale treatment technologies in small communities. Table 2.3 shows the major operational municipal wastewater plants in West Asia countries. Most of these treatment plants are overloaded due to uncontrolled population growth coupled with the slow development of new treatment facilities. For the purpose of this book, available technologies that are used in the region are grouped under two categories; (i) large scale technologies and (ii) community scale technologies.

2.3.1 Large scale technologies

Generally speaking most of the countries in the region do not have specific national standards for wastewater treatment technologies. The following conventional methods are used:
1. Activated sludge plants
2. Trickling filters
3. Aerated lagoons
4. Oxidization ponds or wastewater stabilization ponds

In Egypt, the number of treatment plants are increasing; from 22 treatment plants in 1992 treating about 650 million cubic meter per year to a potential of 123 plants treating about 4.9 billion cubic meters per year in 2005. Two major treatment plants (one is oxidation pond and the other is activated sludge) are completed for Cairo West and Cairo East. They are operating at very good efficiencies. Alexandria, being the second largest city, has a new activated sludge treatment plant with a capacity of 1.3 million cubic meters per day. Most of major cities will have wastewater treatment plants with priority given to coastal and tourist cities like Matrouh, Luxur and the new town in the Red Sea. Other cities in the new developed land (Sina and New Valley) do not have treatment facilities since they rely on septic tanks. The treatment plants of the industrial cities (10^{th} of Ramadhan and 6^{th} of October) are oxidation ponds designed to meet domestic wastewater plus the effluent of the industrial plant (of acceptable standards). In Egypt, although the use of waste stabilization ponds is increasing, activated sludge method is still the most common method.

In Jordan, there are 14 treatment plants in operation now; most of them are overloaded. The largest one is serving Greater Amman and Zarqa district with a population of 1.5 million inhabitants. As-Samra waste stabilization ponds (WSP) were designed for a capacity of 68,000 m^3/day. Currently As-Samra WSP receives influent and organic loading far in excess (2.5 times) of the designed capacity. The plant consists of three trains; each has two anaerobic ponds, four facultative ponds and four maturation ponds. In spite of the excessive loading with respect to the design parameters, the removal efficiency of BOD and TSS at the facilities have declined only slightly. This situation is attributed to the fact that facultative (and probably maturation ponds) are acting anaerobicly, producing offensive odors and impacting several kilometers of the area around the facility. As-samra effluent BOD, COD, and TSS do not meet the Jordanian standard for the discharge of effluent to wadis. The government has completed a study (Herza 1997) for the rehabilitation, expansion and development of existing wastewater system in Amman- Zarqa basin area to treat about 600 m^3/d by the year 2020. For the rest of the country, Table 2.4 illustrates some information on the different operating wastewater treatment plants. By comparing the design inflow to the actual inflow it is clear that 7 out 14 plants are operating under hydraulic and organic overloading.

In Kuwait, about 80% of the population are currently connected to the public sanitary sewage system, which delivers wastewater to four treatment plants. The largest is an activated sludge treatment plant with a capacity of 250,000 m^3/ day serving Kuwait city. There are two other activated sludge plants treating 160,000 m^3/ day and one aerated lagoon of 10,000 m^3/ day capacity. All treatment plants have tertiary treatment facilities with rapid sand filtration producing water of good quality for irrigation.

In Lebanon, about 165 million cubic meter (MCM) of wastewater are produced annually; only 8 MCM are treated as of 1994. During the reconstruction period following the 15 year civil war, the government has completed a preliminary treatment plant in Beirut with a design capacity of 170,000 m^3/day. Beirut treatment facilities employ screening, grit removal and settling. However, the infrastructure in sewer pipeline system has not been completed to connect all the city households to the treatment plant.

In Saudi Arabia, all major cities have wastewater treatment facilities with more than 40 treatment plants. Most of them are under loaded and comply with the effluent quality design criteria. For coastal cities like Al Khobar, Jeddah, and Damam, the secondary clarrifiers effluent is chlorinated before being discharged to the Gulf or the Red Sea. Inland cities like Riyadh have treatment plants, which are mainly activated sludge based with a few that use trickling filters and aerated lagoons. Tertiary treatment consists of rapid sand filters, lime softening, polishing ponds followed by chlorination or ozonation as disinfection. In Mecca, reverse osmosis is used as tertiary treatment before water is allowed to be used for irrigation and other reuses.

Table 2.3: Characteristics of major operational planned municipal sewage treatment plants in WA countries

Country	Number of WWTP	Design capacity in 1000 m^3/day	Type of treatment	Remarks
Bahrain	1 + 9 small scale	125	AS+DF+ O_3	OL
Egypt	22	650	CT+AS+OP+PP+DF+O_3	* 4 UC
Jordan	14	111.4	OP+AS+TF+PP+AL	*1 OL * 4 O *2 UC *2 UE
Kuwait	4	412	AS+AL+RSF	*4 O
Lebanon	3	170	PT	*2 UC *1Disabled
Oman	10	385	AS+RSF	* O
Qatar	8	100	AS+RSF	* O
Saudi Arabia	5	620	AS+TR+AL+RO+LS+F+PP	* O
Syria	7	1182	AS+AL+OP	* O
UAE	3	410	AS+TF+RSF+O_3	* O
Yemen	13	15	OP+CT	-
W. B.	NA	NA	NA	* OL

AL: aerated lagoon	O: operation	RSF: rapid sand filter
AS: activated sludge	O_3: Ozonation	TR: trickling filter
CT: conventional treatment	OL: overloaded	UC: under construction
F: filtration	PP: polishing pond	UE: under expansion
LS: lime softening	PT: preliminary treatment	
OP: oxidation ponds	RO: reverse osmosis	

In Oman, Qatar, and UAE, there are 21 treatment plants (Table 2.3), 24 of them use the activated sludge method and one only of trickling filter type. In all three countries about one million cubic meters per day is treated with rapid sand filters to produce good quality effluent. One plant in Abu Dhabi uses ozonation for disinfection.

In Syria, although about 45% of the population are connected to the sewer system, there was only one oxidization pond near Damascus in 1994 treating about 100,000 m^3/d. During the last three years, seven major treatment plants were completed with a total capacity of 1,182,000 m^3/day for major cities including Damascus. All new facilities are using activated sludge methods with provision for reuse. These provisions include setting up regulations and monitoring procedures. As for another 20 secondary cities in Syria, feasibility studies for construction of new treatment facilities have been completed waiting allocation of funds. The Arab fund has already started providing support to construct these facilities.

In Yemen, there are only 8 wastewater treatment plants that are in operation; 7 of these are oxidation ponds and one is an extended aeration activated sludge in Ibb city. There are another 14 treatment facilities either in the design phase or under construction; most of them will be WSP type. The oxidization pond near Sanaa is overloaded but there is a new one at the construction phases. In cities which do not have treatment facilities, about 20% of the houses are connected to the sewer pipeline discharging their flow to the nearest Wadi. The rest are percolated into the ground.

In the West Bank and Gaza strip, the collection, treatment and disposal of wastewater is the responsibility of the local authorities. The percentage of population connected to the sewer system is 40% and 25% for Gaza and the West Bank, respectively. Other areas that are not connected to the sewer system use septic tanks, cesspools, dry latrine or soak pits. In the whole Palestinian Territories, only eight treatment plants are in operation with a capacity of 54,000 m^3/day. All of these plants are facing problems of operation and maintenance but overloading is their major problem. There are plans in some towns especially in Gaza to build new facilities where construction is on going. These facilities are of the wastewater stabilization pond type.

Table 2.4: Main features of the wastewater treatment plants in Jordan (1996)

No	Treatment plant	Pop. Served Million	Design inflow m^3/d	Actual inflow m^3/d	Design BOD_5 load kg/d	Actual BOD_5 load kg/d	Type
1	AsSamra	1,575	68,000	143,450	35,750	87,361	WSP
2	Aqaba	.03	9,000	6,014	3,510	2,472	WSP
3	Madaba	0.63	2,000	2,437	1,700	3,395	WSP
4	Ramtha	.0277	1,920	1,431	1,651	1,867	WSP
5	Mafraq	.019	1,800	1,298	1,557	1,127	WSP
6	Ma'an	.009	1,590	1,530	1,542	1,602	WSP
7	Irbid	.149	11,000	7,620	8,814	10,218	TF& AS
8	Salt	.052	7,700	3,868	8,400	3,253	TF
9	Jerash	.017	3,500	1,351	4,000	1,698	OP
10	Abu-Nuseir	.021	4,000	1,497	2,720	798	AS
11	Baqa'a	.118	6,000	6,918	5,400	9,153	TF
12	Kufrenjeh	.014	1,918	730	1,630	545	TF
13	Karak	.0138	785	1,164	850	965	TF
14	Tafila	.012	1,600	1,014	1,680	903	TF

AS = activated sludge WSP = wastewater stabilisation ponds
TF = trickling filter OP = oxidation pond

2.3.2 Community scale technologies

There is a wide range of small-scale technologies that are used in West Asia countries varying from very simple disposal methods to very high compact technologies. The private sector or the local communities operate most of these facilities. In poor rural areas with community population of less than 2000 and where drinking water supply is not adequate, indigenous technologies are in use. These involve the use of dry latrine and separate system for water use in bathing and in the kitchen. There is not much information available about this. In all small areas where running water supply is available, the use of septic tanks is common. Many countries in the region are encouraging the use of small-scale treatment facilities. This will reduce the involvement of the public sector and increases the private sector participation. Oman is a leading country in this regard, with several locations spread over the country have small scale sewage systems connected to their own wastewater treatment plants. There are more than 250 treatment plants in Oman with capacity ranging from 8 m^3/day to 10,000 m^3/day serving small community complexes, university, major hotels and some industries. Most of these facilities are mechanical treatment plants of multiple tank system with sludge recycle such as the Biogreen system of Japan.

Major hotels in tourist areas or along the beach in Jordan, Egypt, Saudi Arabia and other Gulf States located in non-sewered areas have their own package plants operated by the private owners.

The use of low cost technologies for small communities in the region are still at demonstration or experimental scale. Small-scale anaerobic low cost technology in a form of two-stage UASB reactor has proven to be 70% efficient in treating wastewater under arid condition. These results were concluded from a long-term research program carried out in Jordan, Egypt and the West Bank. As a result of that the government of Jordan will start pilot projects to treat wastewater of scattered villages in the Jordan Valley. The first stage involves establishment of treatment stations where wastewater will be collected from cesspools and trucked by tankers. Post treatment technologies will accompany UASB reactors that will have a capacity of 800 or 1000 m^3/day.

Similarly, the use of wetlands for small communities is still under investigation by research institutions, but its acceptance by decision makers faces some reservation as it consumes water during treatment processes. It appears that engineers in the region are oriented to the use of mechanical systems and do not prefer the use of low cost technologies.

For the protection of the environment, it is necessary to cover small areas and small communities with treatment facilities. The option will be to use low cost technologies that require less investment and operation cost and does not require well-trained engineers to operate.

2.4 Reuse (Topic d)

Treated wastewater is now being considered as a new source of water that can be used for different purposes such as agricultural and aquaculture production, industrial uses, recreational purposes and artificial recharge. Using wastewater for agriculture production will help in alleviating food shortages and reduce the gap between supply and demand. The interest in the reuse of treated effluent has accelerated significantly in the West Asia region since 1980 for many reasons;

- Expansion of sewerage system networks and the increasing number of treatment plants.
- Production of large quantities of wastewater which makes its use for agriculture a viable alternative.
- Wastewater is a rich source of nutrient and can reduce the use of fertilizers.
- The reuse is a safe disposal of wastewater which will reduce the environment and health risks, and
- The treatment of wastewater to be used for irrigation is cheaper than that needed for protection of the environment. Regulations to discharge water into sea and streams or groundwater recharge are more strict than reuse for irrigation.

In addition, the reuse potential in West Asia countries is very high due to the extreme water scarcity. Now, there are at least eight countries in the region that operate modern wastewater reuse facilities for agriculture production. About six countries are practicing reuse in unplanned uncontrolled and direct use for irrigation without restriction. In Yemen, Syria, Lebanon, Palestine Territories, Egypt and Iran, raw sewage is being used for agriculture production. Three countries in the region discharge raw wastewater to the surface water (rivers) without considering management of reclaimed water as a source. In Bahrain, about 12MCM of tertiary treated wastewater is used for irrigation of fodder crops in a government farm. Some private farmers are using treated effluent for the production of alfalfa. At present the remaining part of their 50MCM treated effluent is discharged to the sea. The government of Bahrain is planning for full utilization of the treated sewage effluent for irrigation purposes by the year 2005. This of course will reduce the pressure on their already mined groundwater resources.

In Egypt, the practice of reuse of wastewater started in Cairo city in 1911 to irrigate Jabal al-Asfar farms covering an area of 1260 hectares. In 1994, about 200MCM of treated wastewater was estimated to have been used for irrigation; the rest of about 450MCM was discharged to surface water bodies of the Nile, drainage canals and the sea. By the year 2000, the treated wastewater production will reach a potential of 4.9BCM per year. This amount is planned to irrigate an area of about 400,000 hectares of desert land.

In Jordan, the volume of treated wastewater produced in 1998 reached 74MCM per year, of which about 95% is reused for irrigation. The reuse of treated wastewater in Jordan reached one of the highest levels in the world. About 80% of the treated effluent is discharged to Zerqa river where it is collected and stored downstream in King Talal Dam to be used for restricted irrigation in the southern part of the Jordan Valley. The remaining 20% which is not located within the Zerga river watershed, is reused on-site. The treatment and reuse of this vital resource is well organized. Future plans aim at improving the quality of effluent and expanding its reuse in other areas in the upland.

In Kuwait, about 25% of its agriculture and green areas is irrigated using 52MCM of treated wastewater. The rest is either used for artificial groundwater recharge through basin filtration or being discharged to the sea. For the rest of the Gulf States, the future aim is to achieve a high quality effluent through secondary and tertiary treatment for irrigation of green areas and ornamental trees in the streets.

In the Palestinian Territories (West Bank and Gaza), the untreated effluent was used for irrigation of trees and vegetables in an uncontrolled manner. The situation will improve in the future with the heavy involvement of donor agencies and the Water Authority in reconstructing the whole water supply and sanitation infrastructure.

The trend in other countries like Lebanon, Syria, Iran, Iraq and Yemen is to expand the use of wastewater for irrigation. In Iran, for example, there is about 70 MCM of primary treated effluent that is used for irrigation. The new management reform action related to the water sector considers wastewater as a new source that should be used for irrigation.

Farmers in Yemen living near discharge sites of wastewater in major cities like Sanaa and Taiz are practicing reuse of non treated or partially treated effluent. Wastewater from the waste stabilization pond near Sanaa Airport is conveyed through open channels to agriculture plots where farmers use the water for irrigating maize, wheat and barley. At present, there is a continuous development in Yemen to implement sewerage networks and treatment plants. The produced wastewater can reach 40MCM by 2005 where it will be used for irrigation.

Artificial recharge of groundwater is another option for reuse of reclaimed wastewater either directly or indirectly. By this, the already over exploited aquifers in the region can be restored. Few cases of artificial recharge have reported in the region; especially in Oman, Egypt and Jordan.

The cities of Ismailiyah and Suez of Egypt and Aqaba of Jordan use the effluent of their wastewater stabilization ponds for artificial recharge of groundwater via rapid infiltration basins.

Table 2.5 summarizes the current type of reuse in the West Asia region and describes the level of treatment and restriction regulation on crop selection and disposal to the sea. The reuse opportunity potential in West Asia is very high due to the following conditions:

- Extreme water scarcity, which affects economic development with little chance to create feasible alternatives for a water supply having excellent quality and competitive price as in the case of reclaimed water.
- Wastewater is a good reliable source and if there is a good design for reuse, there will be no health problems expected.
- The reuse capital investment can be paid back with a reasonable period for both suppliers and users.
- The socio-cultural acceptance is there.

In most West Asia countries sewage effluent provides a convenient and economic source of water for irrigation. In the last decade there has been a significant move to formalize health risks and use the treated effluent with the highest possible efficiency. In addition to wastewater being reused, nutrients can be recycled through irrigation as well. This will protect water bodies from eutrophication and will at the same time use the fertilizer value in the reclaimed wastewater to meet the fertilizer requirements of a wide range of crops.

Table 2.5: Summary of existing and proposed re-use installations in West Asia countries

Country	Reuse application						Level of sewage treatment			Policies
	Roads	Parks	Indust	Aqua-culture	Agri.	AR	Primary	Second-ary	Tertiary	
Bahrain					*				*	O_3+ R
Egypt				*	*	*	*	*		ND
Iraq							*	*		To river
Jordan					*	*		*		R
Kuwait					*			*	*	R
Lebanon					*		*			ND
Oman	*				*	*		*	*	R
Qatar	*	*							*	TI
Saudi Arabia	*		*		*			*	*	O_3+R
Syria					*		*			ND
UAE					*		*	*		O_3+R
Yemen					*		*			ND

AR: artificial recharge R: restricted
ND: not decided TI: trickling irrigation

Using reclaimed wastewater in urban areas is not practiced so far, but it appears that reclaimed wastewater reuse in urban areas for toilet flushing and street cleaning is feasible. This is because the majority of countries in the West Asia region face an increasing growth of high-rise buildings, where reuse for toilet flushing is a promising option, since it is the most economic application method for highly-populated urban areas, if a nearby agricultural area is not available. In West Asia countries there are three cities of over three million people, according to 1996 statistics, where this method can be applied. Decision-makers of local authorities must consider this option as a technically feasible option.

2.5 Disposal (Topic e)

Most guidelines and government regulations in West Asia countries for effluent discharge standards are set to comply with WHO guidelines. The application of these standards are not enforced in practice because the effluent standards are too strict.

West Asia countries can be divided into three main categories according to their disposal practices as follows:

- Category 1: Gulf areas, which includes Bahrain, Oman, Saudi Arabia, Qatar, Kuwait, and UAE.

All countries in the Gulf area follow similar methods in the disposal of wastewater effluent. A high percentage of wastewater after post treatment is reused in irrigation of agriculture land or in landscaping while the remainder is disposed into the sea after many advanced treatment techniques. This practice is common in the Gulf region due the well-equipped treatment units and the availability of advanced treatment plants.
Strict quality standards are followed before disposal and reuse, although certain criteria parameters, it is thought, could be relaxed in order to fully utilize the ever increasing volume of secondary treated effluent.

- Category 2: includes Egypt, Iraq, Jordan, and Syria

These countries are following moderate regulations for the disposal of wastewater effluent. Effluent from wastewater treatment plants doesn't meet the national or the international standards. This may be due to the condition or inability of existing treatment plants to cope with loads of raw wastewater influent. Based on this fact a high percentage of the effluent wastewater is disposed to surface water bodies for later use in irrigation. The regulations in these countries specify the types of crops that can be irrigated using this type of treated water. Moreover, this water may be used for landscaping and for industrial purposes. The government does not allow the disposal of raw wastewater in wadies or by over land spreading. Violation of this regulation may appear in the rural areas since they are not served or connected to the sewer system (collection system).

- Category 3: includes West Bank, Iran, and Yemen

A large percentage of the wastewater effluents of these countries are disposed to wadies and subsequently used for irrigation of cropped lands without treatment. In Iran, unfortunately most of the wastewater effluents are used in irrigation without meeting the national standards. Also some of the treatment plant effluent is mixed with stormwater and some industrial wastewater. It has been found that an estimated 240,288 hectares of lands are being irrigated by raw wastewater in six provinces of Iran.

In the West Bank, raw sewage is disposed to the wadies from where it is used for irrigation of all kinds of crops and vegetables. No environmental or health control or consideration is given to the workers, products, soil or the possibility of groundwater contamination.

In Yemen, raw wastewater is used for irrigation wherever it exists and can be used for this purpose without any treatment to meet the standards of wastewater reuse.

Iran, West Bank, and Yemen have faced different difficulties in finding funds to construct water and sewage projects. Also there is a training need for technical operation, maintenance, and management. Furthermore, most of the existing wastewater treatment plants are overloaded and not properly operated and managed.

2.6 Policy and institutional framework (Topic f)

2.6.1 Regulatory framework

Most West Asia countries have issued regulations and standards that are used to implement their wastewater management policies. The application of these regulations is stricter in oil producing countries, whereas they are relaxed in other countries. These regulations cover agencies in charge of, collection of sewage, treatment process and disposal and discharge. In Jordan, Saudi Arabia, Oman, Egypt and other countries, the discharge of industrial and commercial wastewater into the sewerage system is strictly prohibited unless such effluent comply with standards of domestic wastewater. If these regulations are violated, the concerned agencies have the full right to take immediate actions including imposing penalties. All house owners or leaseholders residing in an estate, which is served by a sewerage system network, are encouraged to connect.

The discharge of surface runoff water or stormwater into the sewerage system networks is strictly prohibited. The regulation and standards for the quality of effluent, its disposal and reuse are well established in many countries. In the Gulf States, tertiary treatment of wastewater including ozonation or chlorination is needed before effluent is allowed to discharge into the sea. Receiving water standards are applicable for Egypt, Iraq, Syria, and Lebanon and to a lesser extent, in Jordan.

Lately, regulations and guidelines to direct the reuse of reclaimed water have been given the necessary importance with regard to the associated health and environmental impact. The first proposed guidelines for wastewater reuse in the region were issued in Kuwait in 1976 (Table 2.6), seven years after operation of treatment plants. In 1982 and after thirteen years of uncontrolled use, Jordan issued standards through a by-law, which allows irrigation by wastewater only for trees and fodder crops. Jordanian standards and regulations were updated in 1995 with the following general criteria:

- The treated wastewater must meet the specified standards that vary according to the planned use.
- When treated effluent is used for irrigation of fruit trees, cooked vegetables and fodder crops, irrigation must be ceased two weeks before collecting the products. Fallen fruit should be discarded.
- The adverse effect of certain effluent quality parameters on the soil characteristics and on certain crops should be considered.
- Use of sprinkler systems for irrigation is prohibited.
- Use of treated effluent in the irrigation of crops that can be eaten raw such as tomatoes, cucumber, carrots, lettuce, radish, mint, or parsley is prohibited.
- Closed conduits or lined channels must be used for transmission of treated effluent in areas where the permeability is high, which can affect underground and surface water that could be used for potable purposes.
- Dilution of treated water effluent by mixing at the treatment site with clean water in order to achieve the requirements of this standard is prohibited.
- Use of treated effluent to recharge an aquifer, which is used for potable water supply purposes, is prohibited.

Table 2.6: Reclaimed water standards in Kuwait

Parameter	Irrigation of fodder and food crops not eaten raw	Irrigation of food crops eaten raw
Level of treatment	Advanced	Advanced
SS mg/L	10	10
BOD mg/L	10	10
COD mg/L	40	40
Chlorine residual mg/L	1	1
Coliform Bacteria count/10mL	10,000	100

Also, standards and specifications for disposal and reuse of industrial wastewater effluent were reviewed in 1995 as standards 202. In Oman and Saudi Arabia, the effluent requirements are set in the regulation and guidelines of wastewater reuse. These guidelines are basically for restricted reuse and mainly for road bushes, ornamental trees and grasses in public parks and recreational areas. In Bahrain, where most of the wastewater is used for irrigation, they apply strict regulations and periodical quality control tests.

In Iran, Syria, Yemen, and the West Bank, new standards and regulation concerning the reuse are in the process of initiation.

2.6.2 Institutional arrangement

With few exceptions, the provision of wastewater collection, treatment and disposal is the responsibility of the public sector either through specialized water authorities or local municipalities. In Jordan, all these activities are under the auspice of the Water Authority, while in Yemen the responsibilities of the National Water and Sanitation Authority is limited only to major cities. In all other countries, the provision of wastewater management is given to the municipalities or local authorities. Major cities in Egypt run their own collection and treatment facilities and provide effluent of good quality to the Ministry of Agriculture, which directs its reuse.

In Syria, for example, the Department of Sewerage at the Ministry of Housing and Utilities is responsible for policy implementation and regulation, while construction and operation of collection and treatment are the duties of the concerned municipalities. The effluent is given to the Ministry of Agriculture for reuse.

In the West Bank, foreign donors rely heavily on NGOs in playing a major role in the improvement of the wastewater management through community participation. The involvement of the Palestine Water Authority in major infrastructure projects for cities like Gaza, Hebron, Ramallah and Nables is directed through official channels. However, NGOs are still playing a major role of management in rural areas.

Monitoring the performance of sewage treatment plants in all Gulf countries is the responsibility of the Environmental Ministries or agencies according to their pollution prevention laws. These agencies are listed in the information sources section. In Oman, it is required that each treatment plant owner should submit a monthly flow analysis showing daily records of the main characteristics of the treated effluent. In addition to that, regular inspections are done by the staff of the Ministry of Environment.

In Jordan, the responsibilities of monitoring and law enforcement are divided among the Water Authority, the Environmental Corporation and the Department of Environmental Health. The mandates of municipalities include the provision of monitoring and surveillance. In many cases, the responsibilities become confused specially for controlling those enterprises or individuals that violate disposal and reuse regulations.

Most countries have established national committees and focal points to evaluate and update regulations and standards concerning the quality of effluent used for irrigation or disposal to the water bodies. The development in legislation is not going parallel with the growing needs for wastewater treatment and reuse. Some countries use standards and specifications applied in the most developed countries like those of California, while others modify the WHO guidelines according to their own conditions.

NGOs in the region are active in some countries like Egypt, Jordan, Lebanon and the Palestinian territories. They usually direct their programs toward lower-income population, launching public awareness programs, training of the personnel and running of small-scale projects. Their main impacts come as they act as pressure groups by raising issues of public concerns like pollution prevention, quality of water and efficiency of treatment plants. Some of the NGOs in the above countries do the monitoring job in hot spots and in affected areas.

Regional agencies like CEHA and FAO are playing a major role in adaptation of new regulations and harmonizing existing laws among countries. They also encourage the establishment of regional standards for reuse of wastewater in agriculture, industry or artificial groundwater recharge. They recommend that regional experiences with effluent reuse should be made more widely available for other countries. They also recommend that legislation should be established to advance construction of sewerage systems and treatment of the industrial wastewater before disposal.

2.6.3 Policy framework

Each country in the region has developed an economic development plan in which the goals and policies expressed the government willingness and determination to enhance the standard of living. Provision of infrastructure services, connection to the sewerage systems and installations of treatment facilities are transparent policies that will be resonated in future planning. A major issue that emerges from these policies is the role that the private sector can play in the provision of wastewater services, in terms of collection, treatment and reuse. On the other hand, the National Environmental Action Plan (NEAP) of each individual country considers environmental issues as the heart of wastewater master planning. Moreover, rehabilitation and expansion of the existing facilities are considered priorities in the NEAP.

The following items are given the due consideration in future planning:

- The deterioration of surface water quality and the potential health impacts on its users.
- The need to conserve and protect groundwater resources.
- The need to conduct environmental impact assessment for future wastewater planning.
- Sustainable development in the region and protecting the natural resources.

Many countries in the region consider treated wastewater as an important water source. Unconventional water resources are incorporated into their water policies. In Jordan, for example, treated wastewater will become a major water resource for irrigation representing 40% of agriculture water share by the year 2020.

2.7 Training (Topic g)

Human resources development and training in West Asia countries, in the area of wastewater, takes places through different mechanisms. They are (a) University education at the level of B. Sc. and M. Sc.; (b) In-service training through continuing education, on ad hoc basis, offered by local and regional institutions or by the private sector; and (c) Meeting, conferences, workshops and short courses. In the region there are quite good numbers of universities, which offer B. Sc. degree in civil engineering with emphasis on sanitary engineering; some of them offer masters programs in environmental engineering. For example, strong environmental engineering programs at masters level are offered at the University of Cairo, University of Alexandria, University of Jordan, King Saud University, University of Tehran, University of Damascus, and the American University of Beirut. These universities and others have played a major role in promoting the sector, as they are the leading institutes in research, development and training. Special and tailor made courses are available on request on a regular basis in the areas of wastewater management, computer aided design, anaerobic treatment technologies and natural systems for wastewater treatments.

The number of specialized research and training centers are becoming more demand oriented entities in providing training courses and organizing specialized workshops and seminars. The Water and Environment Research Center of the University of Jordan in collaboration with National Research Center of Egypt and Beir Zeit University in the West Bank are organizing special training courses on the anaerobic treatment of wastewater for arid areas. Other institution like the Water Research Center of Egypt, the Water and Environment Center of Sanaa University and the Water and Environment Research Center at al Najah University provide the personnel of the water authorities in their countries with needed training.

As a result, the number of professionals in the field of wastewater has increased significantly over the last ten years. In spite of that, most of the major engineering (design and construction) is done by multi national companies with some kind of linkage with local companies. This is partly based on the request of the lending or donor agencies who require well experienced international companies to design or implement the sponsored projects. Therefore, it is necessary that education and training be oriented toward project management, preparation of tender documents and quality control.

A number of international and regional agencies are involved in training such as the Center for Environmental Health Activities (CEHA). CEHA organizes and supports a number of research and training programs in the area of wastewater treatment and reuse. In cooperation with FAO Regional Office in Cairo and UNEP Regional Office in Bahrain, periodic workshops and seminars are also being organized.

It is noticed that most of professionals in sanitation, environmental health and reuse rely on their on the job training or knowledge gained through field experiences and they do not realize the important of refresher courses to update their knowledge. This subject should be brought to the attention of decision-makers in order that staff members of the implementing agencies be allowed or forced to take such courses. They further should consider that as partial requirement for promotion.

The subject of training should also be extended to the level of technicians, assistants and farmers on the use of new technologies and equipment. The situation of manpower is critical, as the technology of wastewater treatment becomes a complex operation requiring a wide range of expertise owing to the interdisciplinary nature of its management. This dictates that the services of various professionals with their corresponding assistants or middle level technicians must be available.
As the interest in the use of treated wastewater has accelerated significantly in the region during the last few years, training programs for farmers or extension agents are needed. Topics, such as selection of irrigation methods, protection of the health of workers and impact of effluent reuse on crops and the environment, can be covered.

2.8 Public education (Topic h)

Public attitudes in most West Asia countries have lately been oriented towards the issues of water quality and pollution prevention. Depletion of the precious water resources especially groundwater and deterioration of its quality causes people to be aware of the problem. The number of incidents of groundwater contamination due to seepage from septic tanks or cesspools has increased during the last ten years. People have also realized the need for wastewater services and projects have to be accompanied by environmental impact assessment (EIA). Public participation in EIA studies and location of the treatment plants have been seriously considered by the water authority. Many projects have been rejected or postponed due to people's objections about location and treatment method. People think that installation of a treatment plant in a location will reduce the value of land adjacent to that plant. Many cases in Jordan have shown that people are more likely to respond positively to treatment plants if they have participated in decision making.
NGOs in many countries such as Egypt, Lebanon, Jordan, and the West Bank are active in public education by organizing and promoting environmental awareness and resource conservation. The Jordan Environmental Society is an active NGO carrying out a national campaign in water conservation, pollution prevention measures including those related to wastewater treatment methods. The Environmental Protection Agency in Egypt is directing its programs of public education toward lower income populations to encourage them to use safe sanitation facilities to improve their health and protect surface and groundwater from pollution. The role of NGOs in the Palestinian Territories is equal to if not more than the role of the local authorities with the new trend in treated wastewater reuse. It is felt that there is a great need to educate farmers about their health and the health of others. They need to be educated on how to use wastewater safely and avoid cultivation of crops that can be used raw. It seems that there is no objection by the people to reuse of wastewater as they consider it as an alternative water resource to satisfy the increasing demand and sustain economic and social demand. This trend is supported by the rulings of the religious scholars that the use of wastewater is an acceptable practice in agriculture or in industry.

2.9 Financing (Topic i)

The cost of construction and operation of sewerage schemes and treatment plants in the West Asia region appears to be very high. However, there is a wide variation in the cost among countries according to the quality of sewer lines and degree of treatment level. It varies from about 1.0USD/m^3 for countries which use ordinary concrete pipelines and Wastewater Stabilisation Ponds (WSP) to about 4-6USD/m^3 in countries that use good quality sewer lines and advanced treatment processes including tertiary treatments. The cost of treatment varies according to capacity and method, for example in Jordan, the cost of treating a unit volume of water using WSP is about 0.02USD/m^3 compared to 0.23 USD/m^3 where aerated lagoons are used.

In most of the West Asia countries, the provision of wastewater collection and treatment is the responsibilities of the governments or municipalities, which are funded also by the governments. Except in oil rich countries, priority for investment has been given to providing people with drinking water supply and little attention has been given to building collection and treatment facilities or to improving the existing schemes until recently. Therefore, existing systems are overloaded. The oil producing countries have invested above that required (planning for the future) while for other countries like Jordan, Iraq, Egypt, and Lebanon the investment level is under what is required (50%). The investments of Yemen and Iran in this sector are around 30%.

The government of Oman is encouraging the participation of the private sector in construction and operation of sewerage schemes. In their 1995 strategy, all new housing complexes, hotels, universities, and hospitals are required to add to their infrastructure the provision of construction of collection and treatment system. The operation, maintenance, disposal and reuse are also the responsibilities of the private sector subject to government approval and monitoring

External sources of finance played a major part in investment in wastewater projects for Egypt, Jordan, Lebanon, and Syria. The main sources of finance come as grants from donor countries or loans from lending agencies like the World Bank, European Investment Bank, Islamic Development Bank and the Arab Funds. Oil producing countries rely on their internal funding. Furthermore, their governments provide operation and maintenance costs for wastewater collection and treatment schemes. Very little information on finance is available for Iraq and Iran. As for the new Palestinian Authority, the whole infrastructure of wastewater has to be built with financial support from donors' countries and international agencies mainly as grants or soft loans.

In Jordan, Yemen, Syria, Lebanon, the West Bank and Egypt, upgrading existing facilities and construction of new facilities will require major investments in the next ten years and beyond. Furthermore, the operation and maintenance of the conveyance system and treatment plants will necessitate the allocation of adequate annual budget to guarantee a safe and reliable level of collection and treatment. Financing needs for wastewater projects are competing with other infrastructure projects.

In all countries, tariffs were less than actual cost. For example, in Jordan the collected fees for collection and treatment are about 0.5USD/m^3 plus subscription and taxes compared to the actual cost of 2.0USD/m^3.

In most countries, projects have been operated by public authorities (water sanitation authority) as in Jordan, Egypt, and Syria, or have been contracted for operation by private companies as in some oil producing countries. In recent years, many countries have launched substantial privatization programs and projects in various sectors of their economy. This trend, which is encouraged by the World Bank and other lending agencies, is expected to increase in the future, leading to more private participation of water supply and wastewater projects. There are many international water utility operators and investors seeking such opportunities. In this respect the Water Authority of Jordan has contracted Lyonnaise des Eaux (a French operator) to operate and manage the water supply system to Greater Amman.

There are four main models for private sector participating, namely; (1) Management or Service Contract model, (2) Affermage or Lease model, (3) Concession model, (4) Build, Operate and Transfer model.
Although there are many benefits which would be gained through privatization such as improved efficiency and better services, the social implications of such a trend have yet to be evaluated. The use of public agencies create a lot of job opportunities. What would happen if these agencies turned into private companies? Whether they would employ less people is a community related question being asked in the region.

2.10 Information sources (Topic j)

Arab Fund for Economic and Social Development (AFESD)

P.O. Box 21923
Safat, 13080
Kuwait

Telephone: +965 4844500
Fax: +965 4815750
Email: msaqqar@afesd.qualitynet.net
Contact: Dr. Muwaffaq M Saqqar
Senior Environmental Engineer

Description: The AFESD is a regional development-funding agency. It has 20 Arab countries as members. The AFESD provides loans and equality investments for economic and social development for member states and some other states in Asia and Africa. It also provide technical assistance in the feasibility studies and preparing of projects. The area of water resources development, wastewater collection system, and treatment plants are considered priority areas in the policy of these funding agencies.

Format of information: Project funded, feasibility studies, technology transfer.
Internet: NA
Language: English and Arabic.
Consulting or support services: Responds to request for assistance in coordinating development policies and planning.

Center for Environmental Health Activities (CEHA)

P.O. box 926967
Amman 11110
Jordan

Telephone: +962-6-5524655
Fax: +962-6-5516591
Email: CEHA@WHO-CEHA.Org.jo
Contact: Dr. M.Z. Ali Khan, Coordinator
Dr. S. Al Salem, Senior Program officer

Description: CEHA is a WHO Regional center for environmental Health Activities and is part of the Eastern Mediterranean Regional Environmental health Program. CEHA runs projects in 22 West Asian and North African countries, providing technical support for the strengthening of national capabilities in environmental health. Wastewater Management and reuse information reaches member countries via training courses, conferences, and information exchange programs at national and regional levels.

CEHA carries out the following activities: human resources development, information exchange (CEHANET), technical cooperation, special studies, and applied research. CEHANET provides access to its regional bibliographic databases of technical information, Wastewater management is dealt with under CEHA's Rural and Urban Development and Housing Program.

Format of information: Training materials, including "Reuse of Treated Effluents." Bibliographic database, reports books, audio-visual materials, and a newsletter, 'CEHA News'.
Internet: http://www.WHO.Org
Language: English, French, and Arabic.
Consulting or support services: Human resources development, information exchange, technical cooperation, special studies, and applied research. National agencies, research and educational institutions, and local governments within Member States of the WHO Eastern Mediterranean Region should contact the WHO representative of the requesting country.
Fees: The newsletter and other information exchange are free. For other activities, contact the Coordinator.

Center for Sustainable Development Studies and Application (CENESTA)

W10 Juybar Str., Fatemi Sq.
Tehran 14157
Islamic Republic of Iran

Telephone: 982-1-885-3922
Fax: 982-1-655-9010
Email: Cenesta@technologist.com
Contact: Ms. Khadija Catherine Razavi

Description: CENESTA is an NGO established to contribute to the national effort in promoting sustainable development through public campaign, awareness, seminar and studies. In the area of water, it has promoted the adaptation of low cost technologies in wastewater treatment in rural area to improve the health conditions of the poor communities. CENESTA has conducted a number of activities in Iran. The organization is focusing on the issue of reuse through training and workshops.

Format of information: reports, pamphlets and training material.
Internet: NA
Language: Persian, English
Consulting or support services: Training, public awareness, research and consulting services.

Department of Environment
Ministry of Municipalities and Agriculture

P.O. box 7634
Doha
Qatar

Telephone: 974 320 825
Fax: 974 415 246
Email: NA
Contact: Mr. Mohammad Akber

Description:
The Department of Environment in Qatar is responsible for the protection of environment where it issues regulations concerning wastewater management and reuse. It is also responsible for enforcing these regulations. The department carries out an intensive public awareness program in pollution prevention and water conservation. It monitors water quality of effluent and for irrigation or disposal to the Gulf.

Format of information:
Internet: NA
Language: English and Arabic
Consulting or support services: provide information on water quality.

Department of Environmental Protection
Ministry of Health

P.O. Box 43337
Hawalli 32048
Kuwait

Telephone: 965-484-7756
Fax: 965-245-6836
Email: NA
Contact: The Director

Description: The department provides information on wastewater management and reuse in Kuwait and is responsible for planning and operation of wastewater treatment plants. It issues and enforces regulation and standard concerning treated wastewater quality for disposal to the sea or reuse in agriculture. The operation and maintenance of the sewer systems is the responsibility of the Municipalities.

Format of information: guideline and standards on wastewater disposal and reuse.
Internet: NA
Language: Arabic and English
Consulting or support services: The department provides consulting services to the municipalities and the private sector.

Department of Water Management
Ministry of Agriculture and Agrarian Reform

Damascus
Syria

Telephone: 963-11-532098
Fax: 963-11-532098
Email: NA
Contact: Dr. George Somi

Description: The Department of water management is responsible for promoting efficient irrigation systems and irrigation management practices by using conventional water supply and treated wastewater. The Department has 14 experimental stations in the country to implement its research programs. The data bank located in the head quarter office in Doma, Damascus provides information on water resources including treated wastewater and their uses. The department will issue guideline concerning health aspects of wastewater reuse by farmers.

Format of information: Publication, progress reports, computers print out, guidelines.
Internet: NA
Language: Arabic
Consulting or support services: provide support to farmers for design and management of irrigation system. It also provides training programs.

Economic and Social Commission for West Asia (ESCWA)

P.O. Box 11-8575
Riad Solh Circle
Beirut, Lebanon

Telephone: +961 -1 –981301
Fax: +961 –1-981510
Email: Abdulrazzak.escwa@un.org
Contact: Dr. Mohammed Abdul razzak and Mr. Omar Tukan

Description: ESCWA is a UN agency that deal with all aspect of economic and social development in 20 countries in west Asia including water resources, environmental development and natural resources. It works closely with the environmental and housing agencies dealing with environment and wastewater management and services. It provides funding and expertise for consulting and backstopping activities in the area of wastewater treatment and reuse.

Format of information: Report, proceedings, environmental guidelines and standards and material for skill development and training.
Internet: http://www.ESCWA.Org.Lb
Language: English, French and Arabic.
Consulting or support services: Provides funds and technical support services to member states.

Also maintain library services. All materials are distributed free.

Inter-Islamic Network on water Resources Development and Management (INWRDAM)

P.O. Box 1460 Jubieha
Amman 11941
Jordan

Telephone: +962-6-5332993
Fax: +962-6-5332969
Email: inwrdam@amra.nic.gov.jo
Contact: Dr. Murad Jabay Bino

Description: The INWRDAM is body, which belongs to organization of Islamic conference (OIC) that deals with the advancement of cooperation in water resources management and its participating states. In cooperation with other international, regional and national organization, it provides training programs in the area of water resources management, domestic and industrial wastewater treatment technologies. It also organizes workshop, seminar and conferences. The network presents case studies on water conservation, recycling and reuse, and appropriates treatment methods. The network objective is to facilitate exchange of information and technology transfer among its member of OIC including west Asia.

Format of information: Newsletter, proceedings.
Internet:
Language: English.
Consulting or support services: Provides fellowship for the training programs, which offers.

Islamic Development Bank (IDB)

P.O. box 5925
Jeddah 21432
Saudi Arabia

Telephone: +966-2-6361400
Fax: +966-2-6366871
+966-2-6360329
Email: mkoshman@isdb.org.sa
Contact: Mr. Mahoud Al-Koshman

Description: The IDB is a regional development bank for 52 Islamic countries in Asia an Africa. It is one agency for the organization of the Islamic conference. The 14 countries of WA are members of the bank. The bank makes loans and equity investments for the economic and social development of Islamic countries, provides technical assistance in preparing and execution of developments and catalyze investment of public and private capital for development purposes. Most of the Bank's project include water resources development, wastewater collection and treatment, and reuse projects. So far the bank has provides loans to member states of more than 16 Billion US dollars.

Format of information: Technical Bulletins, Studies and projects reports.
Internet: http://www.isdp.org.sa
Language: English, French and Arabic
Consulting or support services: Respond to requests for assistance in coordinating development pollicies and planning.

Ministry of Environment

P.O. Box 3773
Damascus
Syria

Telephone: 963-11-3330510
Fax: 963-11-3335645
Email: NA.
Contact: Engr. Yahya Aridah

Description: The ministry of environment handles all environmental matters at the national level. It puts regulations governing house connection, collection, treatments and disposal of wastewater with the coordination of other agencies and municipalities. It is responsible for enforcing these regulations. It works with the Ministry of health, Ministry of housing and utilities and the department of water management in promoting sustainable reuse of treated wastewater for irrigation.

Format of information: Progress and monitoring reports.
Internet: NA
Language: Arabic
Consulting or support services: Information about environmental activities in Syria.

Jordan Environment Society (JES).

P.O.Box: 922831
AbdulHameed Badies St.
Al Shumeisani, Amman
Jordan 11192.

Telephone: 962 6 5699844
Fax: 962 6 5695857
Email: jes@go.com.jo
Contact: Mr. Mahmoud Al Omari

Description: Jordan Environment Society (JES) is an NGO aiming at environmental protection and pollution prevention. As of October, 2000 the number of members exceeded 6000 and 70 organization; about 40% of them are females. The society has 24 branches in major cities of the country. JES main mission to create public awareness in environmental issues through seminar, workshops and public hearing. Since 1990, JES in cooperation with GTZ and USAID has carried out two project; one in environmental awareness issues and the second project is on water conservation and protection implemented through public campains.

Format of Information: Proceedings of seminars, training material, pamphlets.
Internet: NA
Languages: Arabic and English
Consultation and support Services: Public awareness, Training and consulting services.

Ministry of Housing and Utilities
Department of Sewerage Management

Damascus
Syria

Telephone: NA.
Fax: NA.
Email: NA.
Contact: Eng. Mahmud Abu Allam; and Eng. Sadeck Abu Watfa

Description: The department of sewerage management of the Ministry of Housing and utilities serves as a national organization in Syria for planning and infrastructure development for sewerage systems. It has taken the planning of construction of 8 treatment plants in Syria. The Department is responsible for policy, monitoring and training while Municipalities are in charge of operation and maintenance of sewer network and treatment plants. The department acts as a national focal point for wastewater management and reuse.
Format of information: Management plan, national guideline.
Internet: NA
Language: Arabic
Consulting or support services: It provides technical assistance to municipalities.

National Water and Sanitation Authority (NWSA)

P.O. Box 104
Sana'a
Yemen Republic

Telephone: 967-1-250158
Fax: 967-1-251536
Email: NWSA@y.net.ye
Contact: Dr. Mohammed al Saeidi

Description: NWSA is a government body responsible for the planning, development and administration of water supply and sanitation projects in urban areas of Yemen. They have completed the design of 8 treatment plants for major cities in Yemen. NWSA is receiving support from different UN organizations and through bilateral cooperation with other countries' agreement like GTZ of Germany. Funding for its sewerage system and treatment plants comes as soft loan from regional or international funding agencies like the Islamic development bank and the Arab fund for economic and social development.

Format of information: Reports, regulations and standards, policy paper, guideline and manuals.
Internet: NA
Language: English and Arabic.
Consulting or support services: They provide technical advice to other government agencies.

Palestinian Hydrology Group (PHG)

P.O. Box 25220
Jerusalem-Shufat
West Bank

Telephone: +972-2-6565887
Fax: +972-2-6565890
Email: Phg@Palnet,com
Contact: Dr. Abdel Rahman Tamimi

Description: The Palestinian Hydrology group (PHG) is a NGO is established to contribute the effort of solving the growing problems of water and sanitation in the Palestinian territories.
As NGO, PHA is receiving funds from different foreign and international agencies to implement small-scale projects in rural areas such as rural water supplies, sanitation and reuse of wastewater for irrigation. PHA is implementing a national wide program on public awareness on many environmental issues.

Format of information: Project progress reports, public awareness leaflets.
Internet: NA
Language: English and Arabic
Consulting or support services: Share information.

Palestinian Water Authority (PWA)
Palestinian National Authority

Orabi Street-El-Remal-Gaza-Palestine

Telephone: 972-7-822696
Fax: 972-7-822697
Email: wrap@trendline.co.il
Contact: Mr. Nasir al Dein

Description: The Palestinian water Authority (PWA) has been established immediately after the announcement of PNA. It is in a charge of all water-related activities in PO including wastewater management and reuse. PWA is an organization, which is growing very progressively and trying to build its own capacity through human resources development and training. PWA is the official agency in charge of supervising of construction of sewage system and treatment plants. The authority is in charge of coordinating research among different institution in Palestine.

Format of information: Pamphlets, reports.
Internet: NA
Language: English and Arabic
Consulting or support services: Information about the water resources use, ground water aquifer and treatment plant facilities.

The Center for Environment and Development for the Arab Region and Europe (CEDARE)

2 El Hegaz St. CEDARE Building, Heliopolis
P.O.Box: 1057
Heliopolis Bahary
Cairo, Egypt

Telephone:	202-4513921/2/3/4
Fax:	202-4513918
Email:	cedare@ritsec1.com.eg
Contact:	Dr. Kamal A. Sabet; Executive Director Ms. Gilan loutfy; Senior Secretary

Description: CEDARE has been established within the Arab Region and Mediterranean Europe to assist the region in implementing global and national environmental programs within the framework of Agenda 21. CEDARE main mission is promote skill in environmental management, technology transfer and environmental education. Another objective of CEDARE mission is to assist member countries in management of fresh water resources and land development.

Format of information: Project Reports, Website, Newsletter, Feasibility studies, Proceeding of Conferences.

Internet: www.cedare.org.eg
Languages: English and Arabic
Consulting or support services: Respond to request for assistance in environmental issue, Water management and wastewater treatment and reuse.

The General Corporation for Environment Protection (GCEP)

P.O. Box 2410-35206
Amman
Jordan

Telephone:	+962-6-5350149
Fax:	+962-6-5350084
Email:	Gcep@go.com.jo
Contact:	Dr. Salih Share'

Description: GCEP aims to promote protection of the environment and the improvement of its various element and the execution of its policy in cooperation with the revenant authorities through:

- Setting-up general polices for the protection of the environment, preparation of the national strategies needed.
- Measurement of elements of the environment and their follow-up through the accredited laboratories by the council.
- Preparation of specification and standards for the elements of environment.
- Implementation of research and studies related to the elements of the environment.
- Supervision of public and private establishment and others, to evaluate the extent of compliance with the approved specifications and standards of the environment.
- Publish printed material concerning the environment.

Format of information: Scientific researches, Annual reports, contracted research.
Internet: NA
Language: English.
Consulting or support services: issuance and specifications and standards regulating and monitoring of different environmental issues. Conduct EIA studies.

Water and Environment Center
University of Sana'a

P.O. Box 13886
Maeen Post Office
Sana'a, Yemen

Telephone:	967-1-250514
Fax:	967-1-250514
Email:	Susihe@y.net.ye
Contact:	Dr. Yousef Al Mooji

Description: The water and Environment Center within Sana'a University was established on the basis of considerations of institutional development as well as the large needs in Yemen for research and training in the water and environmental sectors. The main objectives of the Center are:

1. To create a challenging, rewarding and sustainable academic environment for university staff active in the field of water and/or environment, in order to enhance their productivity in this professional field.
2. To conduct research related to the development and management of water resources and the protection of the environment within the Yemeni context.
3. Transfer of knowledge related to water and environment, through training and contributions of awareness raising.

Format of information: Country papers, training material, and reports.
Internet: NA
Language: English and Arabic.
Consulting or support services: Organize training programs, contract research, provide consulting and analysis services.

Water and Environmental Research and study Center

University of Jordan
Amman
Jordan

Telephone: +962-6-5355000
Fax: +962-6-5355560
Email: water1@ju.edu.jo
Contact: Prof. Muhammed Shatanawi

Description: The center is a multidisciplinary unit at the university of Jordan conducting research, studies and training in the area of water and environment. The center is carrying out intensive research on wastewater treatment using low cost technologies such as anaerobic treatment (using UASB), wetlands and the use of aquatic plant (algae, duckweed). The center has promoted the use of UASB as an alternative low cost method for wastewater treatment for small-scale communities. Research is being carried out on the potential reuse of treated wastewater for irrigation and its long-term impact on soils, crop and human health.
The center provides training programs on different treatment technologies, reuse of wastewater for irrigation and environment impact assessment of wastewater collection and treatment projects.

Format of information: Technical reports, bulletins, scientific papers and annual reports.
Internet: http://www.ju.edu.jo.
Language: English and Arabic.
Consulting or support services: Conduct researches and provides services as chemical and biological analysis of drinking water and wastewater.

Water Pollution Control Department
Nation research Center

Dokki
Cairo, Egypt.

Telephone: 20-2-3371615
Fax: 20-2-3370931
Email: Fgohary@hotmail.com
Contact: Dr. Fatma El-Gohary

Description: NRC is a one of the largest key research institute in Cairo holding 13 research divisions and a large number of scientific staff. The Water Pollution Control Department (WPCD) of NRC is involved in various projects related to water management and wastewater treatment. The NRC has an advisory task for local and national institutes responsible for implementation of water treatment methods. There is close cooperation with the various water research institutes of the Ministry of Public Works and Water Resources (MPWWR) such as the Drainage Research Institutes (DRI) and the Water Management Research Institute (WMRI). Particularly in the area where wastewater treatment is liked to reuse by irrigation, an integrated approach is indispensable for local acceptance. Both DRI and WMRI expressed their interest and stressed the need for low-cost effective methods for the reclamation of domestic sewage for agricultural usage.
The NRC institute has a close relation to various universities in Cairo (Ain-Shams university, Cairo University, El-Azhar University). Many students who are graduating from these universities have their practical research period in NRC after which they find their ways to the private or public sector. The NRC effectively can perform dissemination of new technologies with respect water and wastewater management.

Format of information: Reports Scientific papers, conference proceedings, training material.
Internet: NA
Language: English and Arabic
Consulting or support services: Contract research projects, provide training, organize International and Regional Seminar.

2.11 Case studies (Topic k)

2.11.1 Jordan's experience in treated wastewater reuse

Introduction

Jordan is an arid to semi arid country with a total area of approximately 89,400km^2 featuring variable topography. A mountain range runs from north to south; the land slopes gently to the east of the range forming the eastern desert; but to the west, the land slopes steeply towards the Jordanian Valley where the Dead Sea lies at an elevation of – 400m below sea level.

The country water resources are scarce and are directly dependent on the annual rainfall, which varies from 50mm in the eastern desert to about 600mm in the northern mountain. The total available water resources as of 1998 can be estimated at 900MCM per year. With a population of 4.75 million, the per capita share of water is about 190m^3/c/year which is consided to be among the few countries of the world with such a high level of water scarcity. About 600MCM is used for agriculture and the remainder is used for domestic purposes (250MCM), industrial sector (40MCM) and other uses (10MCM).

According to the national water allocation policy, priority of water supply is given to domestic users followed by industry and the remaining will be for agriculture. As such, it appears that the share of agriculture will drop significantly in the future. The decrease in water allocation for agriculture can be compensated partly by treated wastewater effluent.

Development of sanitation services

Until 1969, cesspools, septic tanks and other on-site methods were used for the disposal of wastewater. This practice coupled with rapid and uncontrolled population growth resulted in major environmental problems especially surface and groundwater pollution. The government of Jordan has realized the magnitude of the problem and the necessity to build a safe disposal system for wastewater. In 1969, the municipality of Amman completed a sanitary sewage system to serve Amman population of 500,000 people. This system was associated with a conventional activated sludge plant with a capacity of 60,000 m^3/day and a BOD loading of 18,000 kg/d. The design effluent standard BOD was 20mg/L and the effluent was discharged to the major tributary of Zerqa river.

Due to the high strength of raw sewage (BOD_5> 600mg/L), the effectiveness of the plant was drastically reduced to the extent that the actual capacity became only 30,000m^3/d by the year 1980. The operation under high hydraulic and organic loading conditions resulted in an effluent that could not meet the standard of BOD_5<20mg/L and low efficiency in the process of solid processes and disposal. As such, the quality of surface and groundwater was deteriorated. This was subsequently used for irrigation downstream.

In the 1980s, the government built a major wastewater stabilisation pond (WSP) system for the Greater Amman Area and other treatment facilities in major cities and towns in the country totaling 14 treatment plants. By 1998, about 50% of the plants were overloaded including the largest WSP of Amman. The government has completed a master plan study to upgrade and expand existing facilities and to build new plants in the country aiming at 90% coverage of the population by the year 2010.

Reuse

At the national level, the total production of the treated wastewater is about 72MCM as of 1998. Nearly all these amounts are being reused mainly for agriculture (95%), about 3% for groundwater recharge and 2% for industrial uses. This practice is a result of the government policy so as to conserve water as a scarce and valuable resource.

Historically the indirect reuse of wastewater effluent has been practiced in Jordan for a number of years, as it has been discharged into the main wadis and mixed with the surface flow. Farmers along the banks of these wadis used to pump water or direct the flow of the wadis and reuse it for unrestricted irrigation. Natural recharge to aquifers takes place through wadis beds. The direct and controlled reuse of treated effluent in Jordan has been increasing since 1985. The government of Jordan has introduced new legislation on effluent quality to control its use considering public health issues and protection of the environment. It is mandatory that all treatment plant projects must include a fully designed and feasible reuse scheme. Below is a brief description of reuse schemes that are currently in operation.

Zerqa River Basin Scheme is the largest reuse system in operation in Jordan. There are four treatment plants located in the basin that discharge its treated effluent to Zerqa River where it is collected downstream at King Talal Dam and used for restricted irrigation in the southern section of the Jordan Valley. The largest treatment plant is As-Samra waste stabilization pond treating about 60MCM where most of it joins the flow at Zerqa River. A small portion (2%) of this effluent is used in on-site irrigation of about 1000 hectares planted with olive trees, fodder crops and forest trees. The other plants (Jarash, Abu Nuseir, and Baqaa) discharged about 4.0MCM to the same river. The volume of wastewater contributes to about 55% of Zerqa Rivers annual yield of 110MCM. King Talal Reservoir with a capacity of 85MCM collects surface runoff and treated sewage effluent which means its quality varies from summer to winter. The total irrigated area by the reservoir water could reach 10,000 hectares.

The volume of domestic treated wastewater from Aqaba WSP reached 2.5MCM in 1998. About 1.5MCM is used for irrigating palm trees and the rest is used for artificial recharge using infiltration basins. As for the reuse in Ramtha, Ma'an, and Madaba; these three plants are served with three WSP producing about 3.5MCM (1998) where it is used for irrigating fodder crops and trees.

The rest of the plants (Salt, Tafilah, Karak, Irbid and Kufrenjih) treat about 6MCM. Where their effluents join the stream of wadis. This water is also used by downstream users for irrigation or collected in small dams, which are built on the wadis for later use in irrigation.

There are about 6 small domestic treatment plants serving the residential areas of the employees of major industries (Cement, Phosphate, and Potash) providing about 1.5MCM of water. Some of this water is used for on-site irrigation and the rest is reused in industries for cooling purposes.

Industrial water from the two major industrial cities (Sahab and Al Hassan) is treated separately and is used for on-site irrigation. Scattered industries, whose influent could not join the domestic wastewater, are using their industrial effluent for on-site irrigation like the yeast and paper factories. The effluent of hazardous industries like paint, batteries, chemicals and pharmaceutical are disposed through evaporation or incineration. Phosphate mining and processing is considered one of the main industries in Jordan, which consumes about 20MCM of water. Recently, the processed water has been recycled after settling and filtration. Also, the effluent of treatment plants of Amman Airport and Al-Hussein Medical City are used for irrigation of grasses, green areas and forest trees in the vacinity of the two sites.

Research and reuse

The Water and Environment Research and Study Center at the University of Jordan is a leading research institute carrying out a comprehensive research program on the reuse of treated wastewater for agriculture and other purposes. The research varies from large-scale surveys and baseline studies to field plot experiments and laboratory analysis. The research program started in 1985 of conducting integrated studies of the potential of reuse and its impact on the health and the environment. These studies were conducted on the treated effluent of Amman Airport where an experimental site was selected nearby representing the arid conditions and low rainfall areas. Results showed improved yield production of corn, no salt accumulation, and slight increase in heavy elements concentration in the leaves.

Another experimental site at As-Samra WSP site has been established since 1992 where an intensive research program is conducted. The research program concentrates on selection of proper irrigation method, cropping patterns, salt and heavy elements' concentrations in the soil, different management practices and socio-economical aspects. Potential of growing alternative crops (such as sugerbeats, alfalfa, Sudan grass and local grazing shrubs) showed promising results. Higher yield was obtained using wastewater especially when sound water and soil management has been practiced.

All of the other research activities, dealing with testing low treatment technologies, have reuse components. The effluents of the anaerobic UASB reactor and the constructed wetland are being reused for irrigation. Survey and analysis comparing olive trees irrigated with fresh water with those irrigated with wastewater over 12 years are being investigated.

In 1993 a base line survey of the area of southern Jordan Valley was conducted monitoring soil chemical properties and heavy elements concentrations. This area is irrigated with the release of King Talal Reservoir; a mixture of 1:1 wastewater to flood water. This survey will be used as a background comparison for future studies to evaluate impacts of wastewater irrigation. Masters students are encouraged to conduct their research on this area to investigate any future changes in the environmental parameters that might occur. Socio-economic studies on farmers' behavior and acceptance of using treatment effluent for irrigation are under way by a Ph.D. student

In Bahrain, wastewater of five major cities and districts are treated at the main activated sludge treatment plant at Tubli. This plant receives by tankers the septage of the smaller towns and villages that are dependent on septic tanks. The Tubli treatment plant is overloaded, now receiving an estimated 160, 000 m^3/day as an average flow compared with the average design flow of 125,000 m^3/day. This is having an adverse effect on the operation on the plant in terms of the biological quality of the secondary effluent transferred to the tertiary system. The peak flow during peak hours can reach 200,000 m^3/day . Therefore activated sludge from the secondary clarifiers is carried out to the tertiary filters in excess of the design flow rate. As such the bulking sludge is carried over the outlet weirs. The effect of the sludge carry/ over to the tertiary treatment system is that the filters become rapidly blocked and, as a result, pass through significant numbers of parasites. In the effort to overcome this problem, it is recommended that the capacity of the tertiary process be expanded to 160,000 m^3/d at this stage. For the future, the primary, secondary, and tertiary facilities at Tubli are expanded to 200,000 m^3/d (year 2010 estimate). In addition to the Tubli plant, there are nine other independent sewage treatment plants in the country, which use trickling filters or activated sludge technology; one of them is for the University of Bahrain with a capacity of 8000 m^3/d.

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3. Asia (Pacific)

3.0 Introduction

The Asia Pacific region is an enormous and extraordinarily diverse region, and is characterised by widely varying practices. Urbanisation has been particularly pronounced in the Asia Pacific region in the second half of the 20th century. The urban population in Asia was 1.15 billion in the year 1995 accounting for about 33% of the world's total population. By the year 2025, Asia will become predominantly urbanised with an urban population of 2.5 billion or 55% of the world's total population. This anticipated increase represents a massive and rapid economic and demographic transformation.

Although the Asian and Pacific Region, as a whole, is experiencing rapid urban growth, it is still predominantly rural. The urban growth rate in the region remained high throughout the 1970-90 period: almost one-third higher than global rates over the same period (Economic and Social Commission for Asia and the Pacific "ESCAP" 1993). During the 1980s, urban populations in the developing countries of the region grew at rates of between 3.0 and 6.5 per cent per annum (see table 3.1), with a regional average of 4.7 per cent per annum, the second fastest urban growth rate in the world.

Table 3.1: Urban Population Trends in Selected Countries/Territories of the Asia and Pacific Region, 1980-2020.

Region /county	Total Population 1990 (million)	Urban population as a percentage of total population					Percentage change in urban population territory			
		1980	1990	2000	2010	2020	1980 1990	1990 2000	2000 2010	2010 2020
East Asia:										
PR China	1.153	19.6	26.2	34.5	43.0	50.8	+6.6	+8.3	+8.5	+8.0
DPR Korea	22	56.9	59.8	63.1	67.8	70.9	+2.9	+3.3	+4.7	-5.1
Hong Kong	6	91.5	94.1	95.7	96.6	97.1	+3.6	+1.6	+0.9	+1.3
Japan	124	76.2	71.2	79.0	81.6	84.6	+1.0	+1.8	+1.6	+3.0
Repubulic of Korea	43	56.9	72.1	81.6	86.3	88.4	+15.2	+8.5	+5.7	+2.1
South East Asia:										
Malaysia	15	34.6	43.0	51.2	58.4	64.8	+11.6	+18.2	+7.2	+6.4
Myanmar	42	24.0	24.8	28.4	35.4	43.4	+0.8	+3.6	+7.1	+7.9
Philippines	62	37.4	42.7	48.9	55.7	62.5	+5.3	+6.2	+6.8	+6.2
Singgapore	3	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0
Thailand	55	17.1	22.2	28.9	36.7	44.7	+5.1	+6.7	+7.8	+8.0
Vietnam	67	19.2	19.9	22.3	27.4	35.1	+0.7	+2.4	+5.1	+7.7
South Asia:										
Bangladesh	114	11.3	16.4	22.9	30.3	38.2	+5.1	+6.5	+7.4	+7.9
Bhutan	2	3.9	5.3	7.8	11.4	16.2	-2.6	+2.5	+3.6	+4.8
India	846	23.1	25.5	28.6	33.8	41.3	+2.4	+3.1	+5.2	+7.5
Nepal	20	6.5	10.9	16.7	45.4	30.4	+4.4	+5.8	+6.5	+7.2
Pakistan	118	28.1	32.0	37.9	23.2	53.1	+3.9	+5.9	+7.5	+6.5
Sri Lanka	17	21.6	21.4	24.2	30.7	38.6	+0.2	+2.8	6.5	+7.9
Pacific:										
Australia	17	85.8	85.2	85.5	87.0	89.0	-0.6	+0.3	+1.5	+7.9

Source Compiled from United Nations (1993), World Urbanisation Prospects: 1992 Revision, United Nations, New York.

Note: 1 According to the Government of the Republic of Korea, the figures for 1980, 1990 and 2000 are 68.7, 81.9 and 86.2 per cent respectively,. The figures for percentage change in urban population for 1980/1990, 1990/2000 are +13.2 and +4.3 respectively.

2 According to the Government of Bhutan, the figure for total population in 1990 is <1, the urban population percentage figures for 1990, 2010, and 2020 are 15, 20 and 22 respectively.

In most countries of the Asia and Pacific Region, the proportion of people who do not have access to proper shelter, clean and reliable water, and adequate sanitation in rural areas is higher than in cities and towns. Although, urban areas have better basic infrastructure and services than rural areas, the urban poor, who generally inhabit low-income settlements and slums within cities, have limited access to land close to centres of employment. They are also denied regular and full access to basic services and suffer most from the adverse effects of crowding, poor water supply and sanitation.

The major environmental problems facing the Asia and Pacific Region during urbanisation are increasing pollution levels due to concentrated discharge of residuals (gaseous, liquid and solid wastes) into the environment, and destruction of fragile ecosystems in the process of urban development. These problems warrant major concern on three counts: firstly, the prevailing pattern and trend of urbanisation is increasingly more material and energy intensive; secondly, the discharge of pollutants in cities is particularly harmful because they are concentrated; and thirdly, the financial, institutional, technological, and infrastructure facilities available to help control these problems in the region are often found to be inadequate.

One of the greater threats to human health in the developing world is the lack of adequate water and sanitation services. The proportion of the urban population covered by sanitation services is even smaller. More than 420 million urban residents do not have access to even the simplest latrine. Many resort instead to open defecation on land or in waterways. The Asia Pacific region urban poor fit in to this description.

In term of their approach to wastewater and stormwater management, it is useful to characterise these countries with respect to the rapid urbanisation in region. They range from the economically more advanced urban centres of Australia, Hong Kong, Japan, Korea (more developed countries) to middle and low income cities of East Asia and Pacific region (developing countries).

3.1 Wastewater characteristics (Topic a)

3.1.1 Water supply and sanitation

Across the region, the most significant progress in water supply and sanitation was made in East Asia (People’s Republic of China, DPR Korea, Hong Kong, Japan and Republic of Korea). With the exception of the People's Republic of China, the East Asian countries achieved 100 per cent coverage of safe drinking water supply and sanitation in 1990. The People's Republic of China achieved safe water supplies for 87 per cent of its urban population. Other sub-regions have also made great improvements in urban water supply since 1980, particularly in South Asia. However, progress in sanitation has lagged behind, most notably in urban India and Bangladesh. Whilst urban areas throughout the region are now better served with water, sanitation and health services, the urban poor in slums and squatter settlements have generally been overlooked for the reasons mentioned earlier (ESCAP 1993).

The volume of wastewater depends upon water supply coverage and industrial demand. The water supply demand for developed countries is about 250-300 L/person/day, with all of the population having access to water supply service. In the developing countries the water supply demand is about 160-200 L/person/day, with only 60% of the total population having access to an adequate water supply. In urban areas the proportion increases to 90% of the population.

Taking the case of Indonesia, the volume of wastewater introduced to a septic tank system is approximately 160 L/person/day. Typical sources of household wastewater, expressed on a percentage basis are toilet (30 %), laundry (15 %), bath (25%), kitchen (10%) and other (7%) (Caturono et al., 1996).

A survey conducted in Vietnam showed that sewage flows have been calculated on the basis of an average flow of 150 L/person/day, for the year 2015, compared to the long-term water supply demand, which was estimated as 180 L/person/day.

Table 3.2 shows the estimated domestic public water supply and wastewater flows for the different types of cities in Vietnam. Wastewater flows are very uncertain as the flows are not measured in any of the cities. It can be seen that the estimated wastewater flows for the Class I cities (very big cities with population > 3 million) are higher than domestic water supply. This may be explained by the fact that many households are using private water wells and some of these households might also be connected to public sewers. This is particularly common in the South, for example in Ho Chi Minh City (HCMC). The data reveal that water supply is increasing with the city size and that this trend is even stronger with regards to wastewater. Specific wastewater flow is only 39 L/person/day in the Class III cities (big medium cities with population < 1 million), while Class II cities (big cities with population between 1 million – 3 million) flow is 69 L/person/day increasing to 125 L/person/day in Class I cities. This reflects the fact that a smaller proportion of households with flush or pour flush toilets are connected to public sewers or drains in the smaller cities.

Table 3.2: Public water supply and wastewater flows in Vietnam

	Public Water Supply L/person/day	Wastewater/ water supply %	Domestic Wastewater L/person/day	Specific Wastewater L/person/day
City Class I	200	119	238	125
City Class II	180	87	157	69
City Class III	150	62	93	3

With the rapid development of the economy and continued urbanization growth, the amount of water used for industrial and municipal purpose has been increasing. Total water consumption in China in the late 1960's was about 476.7 billion cubic meters, of which 57.2 billion cubic meters of water (about 12% of the total amount) were consumed in urban areas and by industries. The quantity of water used for industrial and municipal purposes in 1993 was about 114.3 billion cubic meters (about 22% of the total amount). Industrial and municipal water consumption in China increased by 100% over 15 years (Lin 1999).

Water supply needs in Central Asia in particular are still poorly served. The progress in sanitation is less impressive, particularly in South Asia where less than 5 % of the rural population in Bangladesh, Bhutan, India, and Nepal had access to adequate sanitation by 1994.

Wastewater from industries depends on the type of industry and degree of industrialisation, which varies from country to country. Volume of wastewater produced per industrial establishment in the Asia Pacific countries is generally less than in Europe.

3.1.2 Characteristics of wastewater

Most of the wastewater in the Asia Pacific Region originates from residential and industrial areas. Septic tanks are the most popular technology in the urban areas of Asia Pacific developing countries, because of its practicality, being easier and cheaper to implement in densely populated areas. About 80 % of the total population in the urban areas have septic tanks.

Septic tanks are the most prevalent form of on-site urban sanitation in the developing countries, for both flush and pour flush toilets. Some pit latrines are also used. Because of small lot sizes in typical urban areas, septic tank effluents over flow in to roadside drains even where subsoil soakage is attempted. Some of these roadside drains are clogged by domestic and commercial solid waste and other debris. In urban areas with waste disposal systems, human excreta and bathing wastewater are directed predominantly to septic tanks. Sullage waste (kitchen and laundry wastewater) may or may not be conveyed to septic tanks.

Characteristics of wastewater, including organic, solid, nutrient, and inorganic substance loads typically result from domestic, commercial and industrial waste. The characteristics vary between countries and also according to location within countries over a period of time. Table 3.3 shows the typical quality of wastewater in some Asia Pacific countries.

Table 3.3: The quality of wastewater in some countries in the Asia Pacific Region

Parameter	Bangladesh	Vietnam	India	Taiwan
pH	6-7.4	7-7.5	9.51-9.62	6.72-7.08
Oxygen mg O_2/l	0.1-5.0	0-6	-	0.7-7.2
Turbidity, FTU	25-300	20-300	18-31	-
Conductivity, $\mu S/cm^2$	-	200-750	1040-2040	493-2040
Phosphorus mg P/l	0.6-5.36	0.2-8	0.16-0.8	0.02-0.96
Total Nitrogen, mg N/l	6.7	35	-	3.56-9.47
Ammonia, mg NH_3/l	-	14.53	-	0.6-35
Suspended solid, mg/l	9-80	50-1700	18-340	-
COD^*, mg/l	4-382	25-400	90-400	42.4-78.4
BOD^{**}_5, mg/l	1-150	100-400	70-220	11.0-27.9

Source: International Specialized Conference on Water Quality and its Management 1988, New Delhi.
Note: COD^* Chemical Oxygen Demand
BOD^{**}_5 5 days of Biochemical Oxygen Demand

For example in Vietnam, Table 3.4 shows that the percentage of households using flush toilets, which dispose of their wastewater on-site, appears to increase with city size. It was expected that the effluents from septic tanks would be infiltrated into the ground. However wastewater in many urban areas is discharged directly into streets, drainage ditches or natural water areas.

Table 3.4: Disposal of domestic wastewater, % of households in Vietnam

	Flush toilets	Disposal to public sewers/drain	On-site disposal from septic tanks
City Class I	84	48	37
City Class II	75	44	31
City Class III	14	25	24
Average North	41	27	14
Average South	91	52	39
Average All	76	44	32

Source: Vietnam National Urban Wastewater and Sanitation Strategy Nov. 1995

At present, the average number of urban households without their own sanitation facilities is about 14%. This corresponds roughly to the percentage of temporary houses (about 19% in 1992 – 1993). Some improvements have probably taken place since then, meaning the share of temporary housing should be lower now. If there is a correlation between households living in temporary houses and households without toilet facilities, then it is likely that households living in temporary housing neither can afford nor are willing to invest in improved sanitation facilities. The population living in this type of housing may be served by communal or public facilities.

Households in large cities generally enjoy a higher sanitation standard than households in small cities. The share of households that rely on bucket latrines and other simple toilet facilities, or do without, is much higher in Class II and III cities.

3.1.3 Indonesia

The sanitation system in Indonesia has its own characteristics. Separating black from grey water introduces high strength domestic wastewater flowing to the treatment process. Consequently, this calls into question community practices and perceptions with regard to domestic wastewater. Effluent wastewater flows out of a primary treatment tank and goes directly to the groundwater. Users do not realise what the consequences of that impacts are to the community, and appear to believe that groundwater contamination is some kind of natural process without any causal factors stemming from it. At the same time knowledge concerning treatment technologies is absent.

The groundwater of the shallow wells is much affected by organics. NH_4-N in the dry season ranges between 0 and 10.7 mg/l and averages 9.0 mg/l. Fecal coliform observed in the dry season ranges between 0 and 460,000 and averages 33,000 (MPN/ 100ml).

In Indonesia the septic tank usually treats only black water and therefore volume intake of septic tanks in Indonesia is estimated to be much less.

The following data in Table 3.5 represent typical physical and chemical parameter effluent concentrations from septic tanks:

Furthermore, bacteria, viruses, nitrates, metals and inorganic contaminants can also be detected. Thus the strength of the pollutant load easily leads to contamination of groundwater. Under Indonesian conditions, the effluent of wastewater to a septic tank is much more concentrated than in Western conditions and so it can be predicted that higher concentrations would be found percolating into the groundwater. To overcome this situation, applied research is required based on conditions specific to Indonesian in order to determine the options available. In this case technical alternatives along with socio-cultural factors seem to be the main considerations.

Table 3.5: Wastewater quality from septic tanks

Parameter	Concentration (mg/l)
Suspended solids	75
BOD_5	140
COD	300
Total nitrogen	40
Total phosphorus	15

(Source: Ir. Caturono, Ir. Gunawan Wibisono, Dip. ES. and Ir. Laksni Sedyowati Environmental Technology: Application in Principle and Practice. Existing Domestic wastewater treatment processes. Paper presented at Universitas Merdeka, Malang)

One district had envisaged installing 2000 latrines as increasing population densities in the district reduced the number of open places for defecation; a problem aggravated for women, who face restrictions in public places. Demonstration pit latrines were provided, but the model sanitation schemes were not adopted and were eventually abandoned. The failure of this aspect of the project lay in the fact that the construction cost of US$ 200 per latrine was far more than most people could afford. Also, the project did not succeed in developing the necessary motivation, skills, and organisation within the District Council to enable it to manage the project's software components. Moreover, the Council was preoccupied with obtaining construction materials for the water supply schemes.

Obviously then, with only four cities operating full scale systems, septic tanks are still the most commonly used operation in Indonesia. However, as a primary treatment system, its efficiency reaches 60% biological oxygen demand (BOD) removal and recent research indicates that important consideration should be given to this typical system because it only treats black water from the toilet, while the grey water flows separately to open drains. Because of this, BOD in the influent to the septic tank reaches up to 830 mg/L and is therefore potentially a source of groundwater contamination, especially considering that the tanks are rarely pumped out (Azwar, 1995). Because groundwater is the main source of domestic potable water in the high-density areas of most cities in Indonesia, it is imperative that groundwater contamination be avoided by selecting appropriate sanitation options.

In the urban centres of more developed countries, such as Australia, Japan, Singapore and Korea, a high degree of sanitation and treatment for public and private flush toilets has been achieved.

The disposal of industrial wastewater to the public sewerage system is controlled in the developed countries. Countries like Australia, Japan, Korea, Hong Kong, and Taiwan do not allow industrial wastewater to be disposed in the public sewerage system unless it complies with certain standards, which are designed to protect the sewage treatment system.

In the developing countries of the Asia Pacific, most of the industrial activities are generally located within residential and commercial areas. Their wastewater is discharged into the public drainage system without pre-treatment or control. This is unacceptable from both environmental and public health points of view, as hazardous and toxic substances may cause much more serious and longer lasting damage to the environment than domestic wastewater.

3.2 Collection and transfer (Topic b)

3.2.1 Sewer and drainage system

In most situations, gravity sewers following the natural topography are used for collecting sanitary sewerage. The components of a typical system are:

House connections:	Also referred to as building sewers, connect to building pumping systems. Normally, the house connection begins outside of the house. In most municipalities, septic tanks are taken out of service when a building is connected to the sewer.
Laterals:	Laterals are the first municipal sewers serving a group of houses. They are usually150mm diameter minimum and located in streets or special easements.
Main Sewers:	Collect from several laterals.
Trunk sewers:	The largest elements, which deliver raw sewage to treatment facilities or disposal points.

The earliest recorded drainage and sewerage developments in the Asia Pacific region were constructed as combined sewerage systems for old cities. This was an accepted design practice in the early 20th century and provided an economical solution to the wastewater collection problem. Many systems were designed to serve only stormwater. As communities grew, many people discharged their sanitary waste into the stormwater drainage and sanitary sewage was then conveyed to natural receiving water. With increased population, the large volumes of sewage being discharge led to water pollution problems. Wastewater treatment was then necessary.

The existing drainage systems, which almost entirely consist of combined sewers without pumping stations, drains and canals, are generally in poor condition due to lack of maintenance. They are poorly designed and constructed, without sufficient hydraulic capacity. Drainage coverage is unevenly developed in the various cities. The length of trunk sewers per hectare and per person are useful indicators, which show that the extent of trunk sewers in most cities in Vietnam is about one-fifth to one-tenth of what would be required for a well sewered city.

Sustainability in urban areas will not be achieved without adequate supply of water and sanitation facilities to support the livelihoods and health of the residents. In recent years, many Asian cities have suffered from inadequate infrastructure, including water treatment and supply. The problem has become chronic in the wake of burgeoning urban populations in the large cities, where sewerage projects have lagged behind relative to population growth (see Table 3.6).

At present sewer and drainage systems in most of the developing countries in the Asia Pacific region such as India, Bangladesh, Sri Lanka, Nepal, Philippines and Vietnam are in very poor condition. Those systems were constructed during colonial times, and need to be upgraded and/or extended. For example in India at present, the sewage network in Mumbai consists of almost 1381 km of main sewage line combined systems, and 51 pumping stations (Parekh, 1995).

Table 3.6: Water service and sewerage coverage in some cities in Asia Pacific areas.

Service	Bangkok	Calcutta	Dhaka	Jakarta	Karachi	Manila	Seoul	Shanghai
Water service coverage, %	82	66	42	27	70	67	100	10
Water availability, m^3/d	24	10	17	18	14	17	24	24
Production, million m^3/d	3.85	1.20	0.78	0.97	1.64	2.8	4.95	4.7
Domestic water use, l/c/d	265	202	95	135	157	202	209	143
Sewerage coverage %	10	3.2	28	-	83	16	90	-
Wastewater treatment, %	-	-	-	-	-	-	-	
Industrial effluent	-	-	-	-	-	-	-	83
Domestic sewage	-	-	-	-	-	-	-	33

Source: Second Water Utilities Data Book – Asia and Pacific Region, ADB 1997.

The earliest records of drainage and sewer developments in Vietnam trace back to the 1870s in Ho Chi Minh City (HCMC) and in the year 1905 in Hanoi, when French engineers planned and constructed the first combined sewers. By 1938 about 11km of pipes had been installed in Hanoi, which at that time had only 150,000 people living in an area of about 1000 hectares. That corresponds to the same level of drainage development as in Class II and III cities in Vietnam today. The drainage system was extended in steps with urban growth during the French period up to 1954, when France gave up its colonial power in Vietnam.

The sewerage system was constructed in the old city from 1905 to 1945, and in the new residential areas after that period. According to the Study on Urban Drainage and Wastewater Disposal System in Hanoi City, the total length of drainage pipe had increased by more than ten-fold to 120 km in 1989, and at about the same level of development as today 29 m/ha (0.13 m/person). The population increased by six-fold to about 900,000 over the same period (VNUWCSS, 1995).

According to a Sewerage Feasibility Study for Saigon City carried out in 1971, Saigon's drainage system consisted of 112 km of pipes in 1970. In 1989, the total length of drainage pipes in the city had increased to 450 km, covering an area of some 14,000 ha and serving a population of 2.8 million. The HCMC Urban Drainage Company is reported to operate and maintain about 500 km of pipes with diameter larger than 400 mm, and an additional 400 km of smaller diameter pipes are taken care of by district authorities. The system consists of 100 km (20%) that are older than 100 years, 250 km (50%) that are 30 to 100 years old, and only 150 km (30%) that are less than 20 years old. The same rapid expansion of the drainage systems has apparently not taken place in other urban areas in Vietnam. In 1975, the cities of Hue, Da nang Nha trang, Phan thiet, and Can tho had a combined drainage pipe length of about 39 km serving a population of about 625,000 people, or 0.06 m/person, which is about the same level of development as today (VNUWCSS, 1995).

These conditions are not unique to the towns of Vietnam only. In the Philippines for example, the Ayala city service area comprising 700 hectares, has 7 trunk lines, 4 overflows, 1,142 manholes and 70 km of pipeline with diameters ranging from 100 to 1050 mm, all of which are in such poor condition that 1060 manholes require urgent replacement. In Metropolitan Manila, only 11% of the population have access to the sewer system.

Although most of the developing countries have poor wastewater collection systems, there are some parts in Thailand and Indonesia where innovative projects for the improvement of sewer and drainage systems have been implemented. For example:

Feasibility study for sewerage and drainage improvement in Phuket city, Thailand.

Like other big cities in Thailand, in Phuket Municipality (the City), there exists a public storm water drainage system which is also used for domestic wastewater removal. However, there is no public sewage disposal system. *(Source: Project for Phuked Municipality in Kingdom of Thailand. Sewage Works in Japan)*

In the city centre, the sullage from kitchens, washing and bathing is discharged to rivers or canals through the existing stormwater drainage system, and approximately one-third of the volume of septage from cesspools and septic tanks is simply allowed to infiltrate into the ground. Therefore, the existing stormwater drainage system is practically refered to as the combined sewage collection system, even though it was not originally planned for such a purpose. This has caused pollution not only of river and sea water, but also of groundwater.

The evaluation of alternatives for planning the sewage collection system for the study area was undertaken. Experience has shown that, for surrounding environmental impact and water pollution control, a separate collection system is advantageous compared with a combined system. However, further analysis shows that under the following conditions, a combined system may be more desirable to promote the diffusion of sewerage more economically.

i) The degree of pollution of the receiving watercourses during rains is acceptable.
ii) The existing public drainage system, which is collecting both surface runoff and sewage can be intercepted to combined sewers to be constructed thus resulting in a lesser need for lateral sewers.

Based on a comparative cost study, the combined system is less expensive than the separate system in terms of construction cost and operation and maintenance (O & M) cost. Construction cost and O & M cost in the combined system are only 30% and 40% of those in the separate system, respectively.

Indonesian sewerage development plan

Because open drainage networks drain stormwater in some areas, two types of sewerage collection systems are applicable depending on the terrain in the collection area. One is the conventional separate system, and the other is the interceptor collection system (Wastewater Disposal Jakarta 1994).

As a general rule, the conventional system is applied for the following areas.
i) Commercial and institutional areas located along main roads.
ii) Residential areas where redevelopment has been completed and the existing road is wider than 2m, which is the minimum width required for laying sewer lines and other dimensions.

The interceptor system is applied for high population density areas, which cannot be covered by a conventional system. This system will collect only grey water through the existing roadside ditches and other drains to the proposed interceptor. Toilet waste is treated by septic tank systems and its overflow flows into the interceptor. The proposed interceptor however, will not receive storm water collected through ditches. Wastewater exceeding the dry weather flow will overflow into rivers or canals in the vicinity.

Jakarta water quality suffers from combination of domestic and industrial pollution. The backbone of the sanitation system is still an open ditch system that serves as a conduit for all wastewater. While this system may have been adequate for the city with a population of less than half a million, which was the size of the city when the system was planned, it can not cope with the wastes of the current 11.5 million residents.

Sewerage systems in more developed countries

Currently, more developed countries such as Australia, Hong Kong, Japan, Korea, Singapore and Taiwan normally have separate systems for sewage, with two types of collection system, one for stormwater and another for sanitary sewage in the new development areas. As development and urbanisation has continued to increase, the pollution load due to stormwater overflow has been found to be significant. Many communities in the developed countries, therefore, provide some degree of treatment to stormwater overflows or store stormwater for treatment at the sewage treatment facilities.

Sewer systems in Australia

In Australia, the community collection system comprises a reticulation system serving individual household properties. The sizes of the pipes, generally gravity pipes, are such that the system can readily accommodate changes in the residential development densities. More recently vacuum collection systems have been introduced in Western Australia.

For local communities, the reticulation system conveys the wastewater to the central treatment and reuse disposal facilities. For large community systems there is generally a main sewer system that conveys wastewater to a large central treatment and reuse/disposal facility. The main sewer system is developed as catchment grows and its capacity can be increased to accommodate flows.

Drainage systems in Japan.

There are two different systems for draining wastewater; namely, the combined system and the separate system. The combined system was first developed in Japan, but to prevent contamination of the receiving water, at present the separate system is primarily used. In Japan, it is common to establish a five-year medium term plan for structures such as sewers. The current five- year plan is the seventh such plan.

The proportion of sewered population in Japan increased very quickly. In 1965, only 8% of population was sewered. By 1970 the sewered population had increased to 16%, in 1985 to 36% and in the year 1993 to 49%. Based on the progress made during previous successive five-year plans the sewered population in Japan is now estimated to be about 65%. Total length is about 11,858 km, with size from 200 to 5000mm.

3.2.2 On-site household - collection

In urban areas with waste disposal systems, human excreta and bathing wastewater are directed predominantly to septic tanks. Sullage waste may also be conveyed to septic tanks. Such wastes are discharged into public sewage or drainage systems in the cities. Usually wastewater flows into sewers by gravity through different levels of sewer through manholes and meets discharge points in rivers, ponds or oceans. The proportion of households with connection to public sewers or drainage is much lower in smaller cities and have proportionally fewer connections and the extent of district sewerage or drainage systems is correspondingly lower. The average percent population in the Asia Pacific developing countries covered by sewage service is about 60% in urban and 1-5% in the rural areas.

The public combined sewer systems consist of concrete pipes, drainage ditches, canals discharging into ponds, lakes, rivers and in some cases to the ocean. The various district administrations manage secondary and tertiary collection pipes within their respective areas.

In most developing countries, sewage from houses with flush toilets flows into drainage pipes. Due to the flat gradient and low flows the water in the drains quickly turns anaerobic and gaseous sulfurous acid corrodes the crown of concrete pipes. Additional maintenance problems are caused by septic tanks that are not emptied frequently enough, resulting in overflow of solids to the streets and drains. The impression is that some of the public service companies have more than sufficient equipment capacity, but the equipment may not be appropriate to reach septic tanks along narrow alleys or too far from major roads, and therefore are not accessible for the large sludge suction vehicles used today. The larger cities, where the change to flush toilets has been particularly rapid, have insufficient as well as inappropriate equipment. As more than 50% of the tanks have been installed during the last 5 to 6 years, problems caused by loss of infiltration capacity due to clogging of the ground, and solids accumulation in existing septic tanks, may not have become apparent or serious enough yet to raise the concern of the households and public authorities.

Normally, sludge from septic tanks should be collected at the request of the households to the urban public or private service. Due to financial reasons households will not request tank emptying services unless there are obvious problems or concerns to the owners or users. Regulations regarding enforcement of regular and compulsory emptying of septic tanks are not in place. This particular problem may, therefore continue unadvised for a long period of time.

There are still many people in Indonesia, both in rural and in densely populated urban areas, who do not have adequate domestic wastewater disposal systems. Most of the wastewater from human activities is directly discharged to an open system, i.e. an overland flow or ground dumping.

In Indonesia, the most common technologies that have been used to deal with community / housing estate wastewater are cesspools and septic tanks, which are combined with infiltration. However, every technology has different constraints to its application and is usually dependent on local environmental conditions.

The septic tank is the most popular technology in urban areas in tropical countries like Indonesia, because of its practicality, being easier and cheaper to implement in densely populated areas. Nevertheless, there are still many problems in determining the construction and dimension of the required tank and soil absorption installation unit to get optimal function from these systems.

3.2.3 Operation and maintenance

The existing drainage systems are generally quite old in the developing countries in the Asia Pacific Region. The physical condition of existing drainage systems is deteriorating due to wear and tear, and neglect of maintenance. The rate of replacement of old pipes is generally much lower than the rate of deterioration of existing pipes, which means that not only will it be necessary to invest in public sewerage to meet future demands, but also to step up investments for rehabilitation of existing systems to prevent further deterioration of sewerage and drainage services.

Serious constraints are caused by a general lack of equipment, spare parts, chemicals, and funds for operation of pumping stations and other facilities. All maintenance is carried out manually, and there is no motorised equipment available for cleaning or flushing out sand, grit and debris accumulating in the pipe. There is also a shortage of financial resources, trained personnel, and of qualified staff for maintenance management.

Pipes have been laid at too flat a slope, and the curb inlets lack adequate sand traps. These deficiencies together with lack of means or equipment for hydraulic flushing contribute greatly to the difficulties of operating and maintaining drainage system.

The existing combined sewers are likely to have serious groundwater infiltration and sewerage leakage problems, which will further complicate proper wastewater management in the future, whether combined or separate sewers are used.

Observation of system failure in most of the Asia Pacific developing countries

Failure in simple sewer systems

Systems are generally characterised by shallow sewer pipes with low gradients. As a matter of fact, the topographical condition of many cities is almost flat with a slope around 0-3% and height 6 m above sea level. Consequently, these shallow systems should be maintained frequently to avoid sludge accumulation in pipes. People have to open manholes every week and flush with buckets of water. However, this maintenance procedure is time consuming and causes damage to concrete manhole lids. Furthermore, for security reasons, people block backyard paths by constructing gates. As sewer pipes are constructed along these paths, workers sometimes can not gain access to desludge blocked pipe sections.

The most popular individual sanitation facility of the area is the pour-flush toilet connected to sewer lines. Almost, all houses are connected to sewer lines, discharging grey and/or black water. However, it has been observed that some households discharge to roadside gutters directly without any pre-treatment for reasons ranging from avoiding connection costs to avoiding maintenance responsibilities.

Failure in private maintenance of sewer pipes

In many instances, entrusting the operation and maintenance of sewer pipes to community organisations has been unsuccessful. They have allowed pipes to clog up, causing people to connect wastewater discharge pipes directly to the roadside gutter as mention above. A typical example is one instance where an oxidation (stabilisation) pond was constructed to receive pumped wastewater as the final treatment facility in the area. The pond was found to have been out of service for many years, due to the pump being out of order. With the objective to avoid the cost of replacing the pump, the sewer line was cut off just before entering the pumping station. The total volume of grey and black water, which had been collected from sewer lines in the area was diverted into the canal adjacent to the empty stabilisation pond, from there it was ultimately channelled into the nearby river.

In general

1) Clogging problems exit in sewer lines and roadside gutters.
2) There is no organised O & M for sewerage and roadside gutters.
3) The community has carried out desludging activities rarely.
4) There is no periodical inspection in the area.
5) The final treatment facility is out of order.
6) All grey and black water is discharged to the canal directly.
7) There exist water born diseases like diarrhoea and skin infection.

3.3 Treatment (Topic c)

3.3.1 Small-scale treatment (household on-site treatment)

The minimum facilities required for most of the households in the Asia Pacific developing countries are latrines and suitable on-site or other means of satisfactory disposal of waste from these households.

Most households use so called "unsealed" septic tanks. This is a two chamber tank with a volume of 2-4 m^3 with open bottom and without overflow pipe. In areas where the ground is too impermeable to allow infiltration, or the groundwater level is too close to the ground surface, there is an overflow pipe that allows the wastewater to flow into the street drains, or elsewhere. The share of households that use on-site disposal in South Vietnam is two to three times as high as in North Vietnam, which underscores the fact the sanitary conditions are better in urban areas in the South than in the North.

It is a common misconception of public officials that septic tanks provide satisfactory sewage treatment and that STE (Septic Tank Effluent) is a satisfactory end product. Septic tanks are meant as pre-treatment for the removal of suspended solids prior to disposal by means of a sub-surface leaching field. Septic tanks remove about 60% of the suspended solids and 30% of the BOD of raw sewage. The effluent still contains most of the organic pollutants and pathogens. The suspended solids that settle in septic tanks are partially stabilised by anaerobic digestion. Biological activities reduce the mass of sewage solids in the tank; however, the septic tank still accumulates solids over time. Typically, in Asia septic tanks are relatively small and should be cleaned every two to three years. If not, solids will pass through the septic tank and into drainage canals.

An estimated 70% of households in developing countries, which have flush toilets, also have septic tanks. Most of these tanks are in very poor condition due to insufficient maintenance. In some cases, solids pass through the septic tank and into the drainage system. In contrast, a fairly large number of households do not have septic tanks, probably in the range of 10%. There are some houses which still use the double vault and bucket latrines. The number of households that are without toilet facilities or rely on such devises as overhang toilets, remains at 20%. This means that the equivalent of primary treatment is provided to only 40-50% of the domestic wastewater flow.

Among Jakarta's 1.4 million poor people, the greatest environmental threat still occurs at the household and neighbourhood level. One recent survey found that in the poorest socio-economic quartile, 31% of the households have neither a piped water connection nor neighbourhood access to a private well, compared with 12% for the city as a whole. In addition, the poorest households were less likely to have neighbourhood waste collection, more likely to share toilets and to have problems with flies both near toilets and in food-handing areas.

Table 3.7 shows toilet types in the surveyed cities of Vietnam as a percentage of households.

Table 3.7: Toilet types in surveyed cities in Vietnam (% households)

City	Class	Region	Flush or pour flush latrines	Double vault latrines	Bucket latrines	No individual toilets
Ha noi	I	North	48	18	16	18
Hai phong	II	North	27	0	23	50
Thai nguyen	III	North	45	0	24	31
Hai duong	III	North	55	33	0	12
Bac giang	III	North	0	0	100	0
HCMC	I	South	91	0	0	5
Da nang	II	South	83	4	0	13
Hue	II	South	63	1	0	36
Can tho	II	South	91	0	0	9
Phan thiet	II	South	36	0	0	64
Nha tranh	III	South	82	0	0	18

Source: Vietnam National Urban Wastewater collection and Sanitation Strategy Nov. 1995.

In developing countries only 8% of urban low-income dwellers have a house sewer connection, compared with 62% of the urban high-income dwellers. Low-income families often share latrines with 100 or more other community members, and long lines or overflowing tanks deter residents from using them at all.

For household wastewater, the available technologies fall into on-site and off-site categories, with a large number of potential technologies in both categories. The three most relevant on-site technologies for urban conditions in the developing countries are summarised below:

The most relevant on-site technologies

- Ventilated improved pit latrine (no water needed)
- Pour flush latrine or flush toilet with septic tank (large capacity septic tanks are required to include both sullage water and excreta)
- Soakaways or soakage pits for septic tank effluent, where soil permeability is reasonable and where distance to ground water table is tolerable.
- Communal or shared facilities for squatter areas (although case-by-case solution will be needed in some locations, for example over waterways)

The most common off-site technologies

- Small-bore sewer (accept septic tank effluent)
- Septage (septic tank sludge, scum and liquid) cartage and treatment in multi-stage lagoons
- Simplified or condominial (low cost) local sewers
- Dry-weather-flow interceptors (to remove septic tank overflow from open drains)
- Conventional trunk sewers and pumping stations
- Treatment of collected or intercepted wastewater by low-cost means, including where appropriate, multi-stage lagoon and/or aquatic plant systems.
- Basic primary treatment and disposal through marine outfalls with diffusers or on land

Criteria for technology selection include

- Effectiveness and operability
- Affordability and cost recovery possibility
- Acceptability to the user
- Availability of trained personnel for operation and maintenance
- Sustainability

In most of the developed countries, 100% of households have flush toilets. These systems function well and are adequately operated and maintained.

3.3.2 Large scale treatment (domestic wastewater treatment)

Suitable treatment methods have been selected for most of the developing countries as shown below:

1- Stabilisation Pond
2- Aerated Lagoon
3- Oxidation Ditch
4- Conventional Activated Sludge

In the developing world, it is estimated that more than 90% of sewage is discharged directly into rivers, lakes, and coastal waters without treatment of any kind. Of India's 3,119 towns and cities, only 109 cities have full wastewater collection and treatment facilities. In Vietnam only the city of Hue has a primary treatment plant with a capacity of 300 m^3/day, which is only 6% of the total municipal wastewater flow. A primary treatment plant for domestic wastewater has been installed in Kim Lien district in Hanoi. The operation of this plant was stopped, presumably due to lack of necessary funds for operation and maintenance.

In Vietnam some ponds, lakes, canals and rivers are used to receive water. They provide natural purification of wastewater, but analyses of water quality from the lakes in Hanoi indicate that the purification capacity has been exceeded. All the surface water bodies are considered enthrophic or polluted by wastewater. During the dry season the bottom layers and sediments are anaerobic. There is danger that many of these natural water bodies will turn anaerobic unless the pollution load is reduced. The canals in HCMC are already overloaded and septic. There are no known operational industrial wastewater treatment plants.

Some Chinese cities have secondary wastewater treatment plants built, but not in operation, one of the reasons being the incomplete status of the associated wastewater collection system. The investment required to establish a complete wastewater system with adequate piping and pumps is much higher than the expenditure on the treatment plants themselves.

In the Philippines there are 1500 cities but only 1% of there cities have domestic and industrial wastewater treatment facilities. Table 3.8 shows details of treatment plants for selected cities in the Philippines.

For small-scale treatment operations in urban and rural areas of Indonesia, the septic tank is commonly used. Large-scale treatment of domestic wastewater could incorporate biological filtration techniques. However, in view of the existing Indonesian situation, it appears that stringent effluent standards will need to be met, meaning that inevitable additions to the primary and secondary domestic treatment processes will be required.

Table 3.8: Water treatment plants in the Philippines

Cities	Capacity of the wastewater treatment m3/day	Type of the treatment	Remark
Ayala	40,000	Activated sludge	Operating
South Manila	207,000	Aerated lagoon	Under construction
Central Manila	162,000	Oxidation ditch	Under construction
North Manila	282,000	Aerated lagoon	Under construction
Dagut	12,600	Aerated lagoon	Under construction
Banguio	20% wastewater	Oxidation pond	Operating
Cauayan Isabela	30% wastewater	Activated sludge	Operating

At present, only five large cities in Indonesia operate centralised sewerage treatment plants: Jakarta, Bandung, Medan, Yokjakarta and Cirebon. Construction of the Jakarta treatment plant was completed in 1992. However, it serves less than 5% of the population. Bandung started the construction of its plant in 1980 and was completed in 1990, serving nearly the whole population. Medan started construction of its system in 1985 and was completed in 1995, covering 75% of the population. Cirebon required three years for the construction of its plant which was completed in 1991.

Thailand is one of the Asia Pacific developing countries with more extensive treatment facilities in its cities. Table 3.9 shows the sewerage plan for 2011 in Thailand.

Table 3.9: Outline of Sewerage Plan and Cost Estimates (facility for 2011), Thailand

Service Area	Design Capacity (m^3/d)	Treatment Method WW	Treatment Method sludge	No. of Operators (person)	Construction (Million Baht)	O&M (Million Baht)
Chai Nat	5,900	SP	DB	13	190.30	0.952
Sing Buri East	3,000	SP	DB	11	185.66	1.286
West	8,200	AL	DB	16	171.56	1.524
Sub-total	11,200	N/A	N/A	27	357.22	2.810
Lop Buri	16,500	AL	DB	21	372.16	4.902
Ang Thong East	N/A	SP	DB	N/A	93.36	0.666
West	N/A	N/A	N/A	N/A	60.39	0.429
Sub-total	3,700	N/A	N/A	11	153.75	1.095
Pa Mok East	2,000	SP	DB	8	117.97	0.432
West	1,700	SP	DB	8	97.34	0.313
Sub-Total	3,700	N/A	N/A	16	215.31	0.745
Sena	2,600	SP	DB	9	84.80	0.241
Rang Sit Preli.	N/A	AS	DU	N/A	182.18	19.123
Rang Sit Others	N/A	N/A	N/A	N/A	1,065.19	29.854
Sub-Total	75,000	N/A	N/A	50	1,747. 37	48.977
Bang Bua Thong Preli	N/A	AS	DU	N/A	352.28	8.189
North Others	N/A	N/A	N/A	N/A	237.33	5.523
Sub-Total	23,600	N/A	N/A	30	589.61	13.712
Bang Bua Thong South	7,900	OD	DB	15	307.55	6.751
Bang Bua Thong Total	N/A	N/A	N/A	45	897.16	20.463

Note : SP - Stabilization Pond DB - Drying Bed AL - Aerated Lagoon DU - Dewatering Unit
OD - Oxidation Ditch AS - Activated Sludge N/A - No Answer

At present, there are 18 Common Effluent Treatment Plant (CETP) sites for tannery clusters in five districts of Tamil Nadu, viz. North Arcot Ambedkar, Erode Peruya, Dindigul Anna, Trichy and Chengai. Out of these, eleven CETPs are in operation, and the remaining are under construction.

In recent years the existing CETPs were found to be operating at a sub-optimal level of performance, as shown in the tables 3.10 and 3.11. Moreover the plants are not meeting standards for inland water discharge. The untreated/partially treated tannery wastewater was being discharged through kachcha nullahs into the river Palar in the district of North Aroct Ambedka, into the river Cauvery in districts of Erode Periya and Trichy and into the river Adyar in the district of Chengal MGR resulting in pollution problems.

Table 3.10: Distribution of CETPs in Tannery Cluster, Tamil Nadu (September 30,1997)

District	Distribution as per Existing Status of CETPs			Total No. of CETPs
	In Operation	Under Construction	Proposed	
North Arcot Ambedkar				
- Ranipet	3	3	2	8
- Ambur	1	1	4	6
- Pernambut	1	-	2	3
- Viniyambadi	2	1	3	6
Erode Periyar				
- Erode	-	-	1	1
Dindigul Anna				
- Dinndigul	1	-	-	1
Trichy				
- Trichy	1	-	2	3
Chengai MGR				
- Chrompet Area	1	-	-	1
- Madhavaram	1	-	-	1
Total	**11**	**5**	**14**	**30**

For domestic wastewater in the developed countries like Australia, Hong Kong, Japan, Korea, Singapore and Taiwan, treatment coverage is from 90% to 100%. For example Osaka has one of the highest rates of sewage service among Japan's major cities, attaining nearly 100% service rate.

There are 1,010 wastewater treatment plants nation-wide in Japan, as show in table 3.12. The use of trickling filter treatment facilities began in Tokyo 1992, while the use of the diffused air activated sludge process began in Nagoya in 1930.

Table 3.11: Performance Details of Operation CETPs during October 1997

Name of the CETP	Desgn Capty m^3/d	Desgn Capty m^3/d	COD mg/l	Inflnt BOD mg/l	SS mg/l	S mg/l	COD mg/l	BOD mg/l	Efflnt SS mg/l	S mg/l
M/sTalco Raniper E. treatment Co Ltd, Ranipet	4000	2142	6556	1789	4015	70	124	4	80	BDL
M/s Ranipet Finished leather E. treatment CoPvt Ltd, Ranipet	2500	1479	4486	1431	1303	6.0	245	15	84	1.2
M/s Melvisharam Tanner Eviro Control System Pvt Ttd, Ranipet	3400	592	3540	1398	854	44	222	<5	78	BDL
M/s TALCO Ambur Tanners Effulent Treatment Co,Ltd Ambur	2170	2218	2948	1450	4692	252	596	110	110	2.8
M/s TALCO Viniyambadi Tanners Enviro Control System Ltd, Vaniyambadi	2800	1800	1411	560	800	11.1	295	19	95	BDL
M/s TALCO Viniyambadi Tanners Enviro Control System Ltd, Udayendiram	400	200	2735	913	2110	65	215	23	93	1.1
M/s TALCO Permanbut Tanners Effulent Treatment Co,Ltd Permanbut	900	496	2070	1180	1200	94	140	22	90	BDL
M/sPallavaram Tanners E. Treatment Co Ltd, Pernambut	3000	2024	7099	2610	3440	80	248	28	216	1.7
M/s Madhavaram Leather Manufacturers Facility Pvt Ltd Chennai	400	227	1968	800	648	30	146	8.0	68	ND
M/s TALCO Dindigul Tanners Eviro Control System Pvt Ltd, Dindigul	2500	1300	4160	1250	2234	210	160	24	92	1.8
M/s Ramij Nagar Tanners E. Co Ltd Trichy	525	264	2526	1236	786	78	132	<3	66	ND

Table 3.12: Number of municipalities with public sewerage Japan

Population (thousands)	Municipalities (Total Number)	Municipalities With sewerage (Number)	Municipalities with Sewage Treatment plans in Operation (Number)
More than 1,000	11	11	11
500 - 1,000	9	9	9
300 - 500	45	45	45
100 - 300	149	148	146
50 - 100	230	218	199
Less than 50	2,793	1,085	600
Total	**3,237**	**1,616**	**1,010**

Osaka treats sewage at 12 treatment plants, with a total treatment capacity of 2,844,000 m^3/day. The basic methods applied for wastewater treatment have been aeration tanks and settling tanks (including primary and secondary). The city's pumping stations discharge stormwater in to the rivers and the sea with a combined drainage capacity of 1,189 m^3/sec.

The beginnings of sewage works in the Republic of Korea can be traced to the dredging and reconstruction of the Cheong Gye River flowing through Seoul City in 1412 during the Lee Dynasty. Under Japanese rule, records show that large-scale construction of storm sewers was conducted.

However, the construction of modern sewerage systems started only after the realization that they are the most important counter-measure for the widespread water pollution problems caused by rapid urbanization during high economic growth in the seventies. As a result, the first sewage treatment works namely the Cheong Gye River Sewage Treatment works (conventional activated sludge process with treatment capacity of 150,000 m^3/day, presently combined with Chun Nam Jong Sewage Treatment Works), was constructed and commenced operation in 1976.

Seoul had only the Jung Rang River Sewage Treatment Works (treatment capacity 360,000m^3/day) serving part of its total population of 8.7 million. Most of the domestic sewage was discharged without treatment into the Han River, a symbol of Korea. The water quality of the Han River was just below the standard (BOD of 6 mg/L) and was gradually deteriorating. Improving the water quality of the Han River and other rivers in the city was an important task for the success of the Olympic Games, on which the image of the Republic of Korea depended to a great degree. Technical co-operation of the private sector has played an important role in the Sewage Works Implementation Plan and started at an earlier stage than the government plan of operation. Specialist engineers from Japan have participated in the execution of basic surveys and design.

The treatment process by the conventional activated sludge method for sewage treatment, and the anaerobic digestion and dewatering method for sludge treatment facilities, were built by the same technology generally used in Japan, except for circular shaped primary and final sedimentation tanks. The sewage works construction plan is shown in table 3.13.

Table 3.13: Sewage Treatment Works Construction Plan in Korea

Number of Sewage Treatment Works	Capacity of Sewage Treatment Works, thousand m^3/d	Cost, in billion won	Rate of Sewered Population (%)
43	7,195	14,320	39
250	12,364	55,678	73

3.3.3 Industrial wastewater

Like domestic wastewater, most of the industrial wastewater in developing countries is not treated, even though most of these countries require that industrial wastewater is treated before being discharged into the sewerage system.

For example in Vietnam there exists only one identified industrial wastewater treatment plant in Vietnam, namely in Hanoi, for tannery wastewater. The plant was financed by UNDP

(United Nations Development Programme) for training purposes, but it is reported by the managers of the factory that due to lack of raw materials, the factory is not in operation at the moment.

The management of industrial wastes, both liquid and solid is generally the responsibility of the respective industries, even more so when government monitoring, control and enforcement of environmental regulations are lacking or absent. The environmental and health impact of uncontrolled disposal of toxic industrial waste is likely to be more serious and longer lasting than for domestic wastes.

Also in Jakarta, industrial discharges are a growing concern. Groundwater is polluted with nitrates and micro-organisms from domestic and toxic waste leached from industrial landfills.

In developed countries, every industrial factory has private treatment facilities. Industries that discharge wastewater to the wastewater system are required to pre-treat their wastewater or provide their own treatment system.

A recent example of a pre-treatment system is the centralised industrial wastewater treatment demonstration plant at Spearwood in Western Australia, which processes the wastewater from a number of local industries and then discharges it to the Water Corporation sewer. Previously, these industries provided their own systems, including discharge into the ocean.

3.4 Reuse (Topic d)

Most of the Asia Pacific countries are tropical countries and their water resources are not very limited. As a result, most of the developing countries do not reuse wastewater except India, China and Vietnam where wastewater is being used for irrigation.

In India, studies on the productivity of crop production have found that recycling and reuse of nutrients and other valuable materials in domestic and industrial wastewater is an effective method for utilising the wastewater. General utilisation of wastewater through reuse and recycling has become very important. In fact, wastewater is a resource rather than a waste since it contains appreciable amounts of nitrogen, phosphorus and potash. Stabilisation ponds can be used for fish aquaculture and the effluent can be used for cultivation of short-term and long-term, ornamental, and commercial and fodder crops.

Wastewater treatment and reuse improves water use efficiency. Wastewater has been adopted as one of the major water resources nationwide, especially in the northern area of coastal cities in China.

Practical experience in China has shown that wastewater reuse not only reduces the demand for fresh water but also can improve environmental quality. Reuse of treated wastewater has the following benefits: make up water supply (reduces demand on good quality water); reduces the wastewater discharge thus reducing water pollution; results in economic efficiency due to lower water cost compared to transporting water from a distant source.

The main potential applications for reuse of treated wastewater in China are in the following fields:

* Agricultural use through irrigation of crops as well as for improving river amenity;

* Industrial cooling especially in the large industrial enterprises;
* Reuse in municipal public areas such as watering lawns and trees;
* Flushing toilets in hotels and residential districts;
* Reuse of the treated wastewater for urban landscape purposes.

Many municipalities set wastewater reuse as a strategy to meet the increasing water demand. To identify the alternatives of wastewater reuse as well as their feasibility and implementation, some cities where water shortage and pollution are very serious such Beijing, Tianjin, Taiyuan, Dailian and Qingtao have been selected as pilot areas for this particular purpose.

In Beijing the main purpose for reuse of treated wastewater is in agricultural production during the irrigation season and to improve river amenity. Some 487 m^3/d of treated wastewater that meets the standard will be available for reuse by 2005, replacing the existing untreated effluent and providing the potential for reducing existing reliance on groundwater resources.

A project of wastewater reuse for industrial cooling purpose has been completed and will be put in to operation soon.

Treatment and reuse of wastewater of a guest house in Jinan city in Shandon Province is an example of reuse of treated wastewater for non-potable purpose in the water shortage area.

The rotating disc biological treatment followed by filtration and disinfection is used for treating the effluent from a hotel. The treated wastewater is reused for watering grasses, make up water of a lake, washing cars and flushing the toilet.

A wastewater reuse treatment plant with a capacity of 50,000 cubic meters per day was built in Tai An city, in which a part (20,000 cubic meters per day) is reused for industrial cooling and landscape purposes after reclamation by tertiary treatment.

In 2000 the municipal wastewater treatment rate will be more than 20 % of total discharged wastewater, and the reuse rate to 10% of municipal wastewater treated in the whole of China. It is forecast that the reuse rate of treated municipal wastewater in 2020 will be up 3-49% in small and medium sized cities and cities with a shortage of water (Lin 1999).

Reuse of wastewater occurs most effectively with on - site or small scale treatment systems. Thus implementation of reuse options in the local context with local community consultation must be seriously considered. Indeed many Western Australian householders are already engaged in the practice of recycling greywater. Greywater is defined as untreated household wastewater, which has not come into contact with toilet waste. It can originate from the shower, bath, bathroom, washing basin, clothes washing machine and laundry trough. The criteria associated with greywater recycling solely for irrigation, as distinct from combined black and grey water reuse, may be less stringent.

A number of greywater recycling installations are also currently in use in Western Australia such as:

Irrigation:

- Woodlots,
- Horticulture,
- Agriculture
- Urban parkland, sports grounds, golf courses etc.

Ground:
- Surface infiltration,

Private garden reuse
Industrial reuse
Disposal via constructed wetlands to surface water
Potable:
- Direct to water supply
- Indirect via groundwater

In the developing countries nightsoil has been used as fertiliser. Nightsoil from buckets and latrines is generally collected by private contractors and sold to farmers, or collected directly by the farmers. Farmers use the nightsoil as a fertiliser and soil conditioner and apply it to agricultural areas without pre-treatment. The urban public service and environmental companies frequently collect nightsoil from pubic toilets with bucket latrines, which is also sold to farmers.

This use of untreated nightsoil is illegal according to current environmental legislation, but the enforcement is overlooked. The Vietnam Wastewater Planing for Urban Areas study, reports that infestation rates of intestinal parasites are more than 95% in areas that use nightsoil in agriculture.

Exact information about the quantities of sludge and nightsoil collected and disposed of by public and private companies is not known. However, Table 3.14 gives information about the average quantities collected from each household according to each city classification. There are insignificant regional differences in sludge and nightsoil collection rates. The relatively large difference in sludge collection rate per household for the various city classes may be the result of several households sharing toilet facilities, and that the survey has not been able to differentiate between houses with own and households sharing in-house toilets. This situation is believed to be more prevalent in the larger cities with blocks of flats. Nightsoil collection rates are, on the other hand, considerably higher per household in the smaller cities, but city sample size may be too low to give an accurate estimate.

Table 3.14: Quantities of septic sludge and nightsoil collection in Vietnam

City	Septic tank sludge		Nightsoil	
	l/d/hh	l/d/person	1/d/hh	1/d/person
Class I	1.27	0.28	0.48	0.11
Class II	0.87	0.16	0.61	0.11
Class III	0.35	0.08	0.85	0.19

Source: Vietnam National Urban Wastewater and Sanitation Strategy Nov. 1995.

3.5 Disposal (Topic e)

Outfall discharges are the most common method of disposal of wastewater for communities located near a surface water body, such as a river, lake or ocean.

Nowadays the design of a new outfall generally requires detailed analysis of wastewater characteristics and applicable regulations and guidelines for wastewater discharge.

Of the wastewater from developed countries which is discharged to a river or the ocean, most will have undergone some form of treatment. The opposite is true in developing countries where only 5 - 10 % of wastewater will have been treated before discharge. It is transported by gravity sewer systems except in low ground level areas where it is transported by pressure sewers using booster pump stations. For all sewer types, pressure dosing by box sewers is being encouraged instead of concrete and gravity systems being used as open ditches and open channels.

Any treatment and disposal eventually returns the water to the water cycle, whether facilitated by infiltration basins, ocean discharge, river discharge, lake discharge, evapo-transpiration from irrigation areas (including the leach drain areas from septic tanks in backyards), ground water recharge to estuaries or other means.

It has been widely recognised that the problem of disposal of wastewater is primarily a matter of communal sanitation, and that the problem is greater in areas of dense population, where civilisation is more advanced, or areas of greater industrialisation.

Therefore there is a need to minimise the amount of contaminants flowing into and collecting in particular disposal areas.

Rapidly increasing municipal and industrial water demands in recent decades have caused dramatic increases in wastewater. Take the case of discharged wastewater during the period of 1985-1995 as an example. The total discharged amount of wastewater in China during that period increased by 100%. A small portion of the wastewater was treated and the remaining 80-90% of wastewater was directly discharged into rivers, lakes and other water bodies, resulting in serious pollution of surface water and groundwater around Chinese cities. In 78% of river sections that flow through cities, the raw water can not meet standards required of a water source for drinking water. Half of the surrounding ground water is polluted. This serious pollution of surface water and ground water resulted in the reduction of the water resource potential (Lin 1999).

Wastewater treatment facilities are inadequate in many cities of the Asian and Pacific Region. In many places, untreated household and industrial wastes are discharged directly into canals and rivers, often contaminating the drinking water supply and spreading disease. The People’s Republic of China, had over 200 million city dwellers in 1980, but only 35 small municipal wastewater treatment plants. As a result, up to 90 per cent of the estimated 37 billion cubic metres of sewerage discharges that year remained untreated. In Shanghai alone, only 4 per cent of the estimated 5 million cubic metres of wastewater was treated. In the same city, in 1979, 96 per cent of surface water samples collected were found to be contaminated with heavy metals. Such heavily polluted water could possibly be a contributor to the rapidly rising cancer morbidity and mortality rates in the People's Republic of China's industrial regions, although scientific evidence to support such a claim is not yet reported (ESCAP, 1993). This illustrates the scale of the problem for developing countries. The impacts attributed to water pollution in selected cities of the Asian and Pacific Region are summarised in Table 3.15.

In Indonesia, river water quality analysis has generated additional water quality results to supplement the existing data. The regional variation of BOD in some areas is wide, ranging from 10 to 255mg/l, and the BOD concentration exceeds 100 mg/l, at about half of the observation stations. The river water BOD in the wet season, however, declines to approximately half as much as in the dry season due to the dilution effects of increased river flow. Fecal coliform exceeds more than 10^6 (MPN/100ml) at almost all observation stations. This means that almost all river water is affected by human wastes to a great extent.

Sea water COD in Jakarta Bay ranges from 18 to 81 and averages 28 mg/l. This COD is composed mostly of soluble COD. Average fecal coliform of the Bay is estimated at 2,530 (MPN/100ml). The Bay, especially at its coastal area, is much affected by human waste.

Table 3.15: Impacts attributed to water pollution in selected cities

City/Country	Impact
Bangkok, Thailand	3 cancer cases/year
Jakarta, Indonesia	Children show signs of mercury poisoning, US$20-$30 million per year to boil water for household use
Kanpur, India	Average fish catch has declined by more than 50 per cent
Kathmandu, Nepal	100 deaths from polluted drinking water
Kuala Gula, Malaysia	Palm oil mill wastes killed $300,000 worth of fish
Manila, Phillipines	8 deaths from contaminated shellfish; total 73 cases of poisoning, 74,390 cases of gastro-intestinal diseases. Shellfish production of 3,430 tonnes in danger of being eliminated; Fishery yield of Manila Bay declined by 39 per cent, Laguna Lake by 79 per cent from 1975 to 1990
Nagpur, India	40 deaths in 1990
Penang, Malaysia	Cockle mortality valued at $750/day
Seoul, South Korea	In 1987, 260 million won ($390,000) were paid by the city for compensation to fishermen
Taipei, Taiwan	Copper in river kills oysters

Source: United Nations Economic and Social Commission for Asia and the Pacific (1993),State of Urbanisation in Asia and the Pacific 1993, New York.

Since the United Nations Water Conference in Asia, many countries of the Asian and Pacific Region have formulated national water policies and plans to regulate the ownership, use and protection of water resources.

In Vietnam there are numerous lakes, rivers and ponds within urban areas. These are used for drainage, flood control, recreational purposes, irrigation, aquatic culture and as receiving waters for wastewater. Hanoi has the largest proportion, with 15% of the city area as natural waters, but HCMC and Haiphong also have large water areas.

Municipal wastewater is discharged without treatment to rivers and lakes. The survey reported that the majority of households have flush toilets, indicating a high environmental standard. Unfortunately this may be deceiving, because most households discharge their septic tank effluent directly into the streets, drainage ditches or natural water bodies. A minority infiltrates the effluent into the ground, although this may vary from place to place according to the soil condition. There is a flagrant lack of environmental management and control with the disposal of wastewater from public as well as private sanitation facilities.

For example, the situation in Haiphong may only be representative for the Red River Delta, where the soil is clayey and not very suitable for ground infiltration, but according to the household Survey, 81 % of sullage from households is discharged to the streets. Among households with flush toilets and septic tanks, only 9% infiltrate the effluent into the ground, 67% discharge directly to the streets, while the remaining 24% to natural waters or wetland.

It is not difficult to observe sewage and sullage flowing long distances along the gutters, mixing with the street garbage, in Haiphong.

3.6 Policy and institutional framework (Topic f)

3.6.1 Regulatory framework

Most of the Asia Pacific countries have introduced regulations and standards that are used to implement their waste management policies. Two example are given, one for a developing country and another for a developed country, to illustrate the situation in the Region. This is followed by general observations of failure in most developing countries in the Region in implementing existing regulations.

Legal system regarding sewerage in Vietnam

The basic law for sewer systems is the sewer law, which defines amongst other things the purpose of sewerage systems, procedures for their establishment, matters related to their use, and control of the water quality for sewerage systems. Moreover, sewerage systems are now classified as basic urban facilities and function to conserve the water quality of public waters.

The City Planning Law and other 'urban redevelopment laws', the Basic Law for Pollution Control, the Water Pollution Control Law and other 'anti-pollution laws' are important as laws relative to the Sewerage Law. The laws regarding sewerage are supplemented by the Emergentcy Measures Law for the Development of Sewerage Systems(see table 3.16).

The main drawbacks of the current system are that the designers and builders are ignorant of established codes and standards. Time and resources are lost in preparing individual design criteria and standards, and the approval is, at least theoretically, open to influence by manipulation and abuse. Finally, the most appropriate and cost effective design for the conditions found in Vietnam should be applied.

In 1995 the Australia International Development Assistance Bureau "AIDAB" financed a study to prepare new design guidelines and standards for water supply and sanitation works.

Table 3.16: Water supply, sewerage and drainage systems standards in Vietnam

Code	Title
TCXD 70-77	Maintenance and operation rules for sanitation facilities of industry and civil construction works
TCVN 5576-91	Water supply and sewerage systems, technical management rules
TCVN 3988-85	Design documents and work drawing standards for construction of water supply and sewer networks
TCVN 4038-85	Terminology and definitions for water sewer age and drainage systems
TCVN 2622-78	Fire fighting water
2OTCN 51-84	Standard branch sewerage and drainage system and works. Standard design
2OTCN 66-91	Operator of water supply and sewer system safety
Sector Standard	Design criteria for water distribution systems and structures
Sector Standard	Drinking water quality standards

National Sewer Development system in Japan

The administrative organization in Japan is made up of one office and 12 ministries. The Ministry of Construction is in charge of sewerage administration.

The Environment Agency establishes environmental water quality standards and controls effluent quality for the conservation of water, air and the natural environment. Effluent from sewage treatment plants is controlled in the same manner as wastewater from industrial plants.

The Ministry of Autonomy authorizes issue of local bonds, which are a significant financing source for the development of sewerage systems, and it subsidizes part of the cost for their redemption in the form of a local allocation tax.

The Ministry of Construction is in charge of guidance and supervision of local autonomous entities for the National Treasury. The City Bureau has a Sewerage and Sewage Purification Department under which the Sewage Planning Division is placed. The Sewage Purification Department is in charge of administration for approval of comprehensive programs for the development of the sewerage system in catchment areas, authorization of public sewerage, basin-wide sewerage, related other projects, and granting subsidies.

The Public Works Research of the Ministry of Construction has a Water Quality Control Division under which the Sewerage Section, Water Quality Section, Ultimate Disposal Section and Advanced Treatment Section are placed to carry out work on sewerage related issues.

Observation of regulatory framework failure in most of the Asia Pacific developing countries

Low priority of the wastewater sector

There are positive statements concerning sanitation, public health and environmental protection in the long term development strategies of Governments. However, these do not seem to enjoy a very high priority. Sustainable sanitary improvements are not possible without clearly indicated demand for these improvements. Sanitation is a commodity much more difficult to sell to customers than, e.g., drinking water. Therefore, the demand needs to be generated by social marketing, social pressure (solidarity), legislation, regulations and enforcement, and government incentives or budget allocations. This structure for demand generation is still very weak.

Overlapping responsibilities and duties

The roles of various organizations, have to some extent, been clarified and streamlined in the past years. There is still some overlap in the duties and responsibilities of for example health, environmental, and water resource authorities at ministry level as well as at the provincial / city level. The project preparation, appraisal and approval procedures are particularly complicated, involving much organisation and management.

The operational power, from the operation of utilities to generation of implementation investment, is decentralised to provincial and city levels. These local levels have sufficient authority to establish a good basis for client awareness management. However, this approach calls for skilled and motivated staff in every province, and local financing though revenue collection. Provinces do not receive central government revenue allocations.

At the utility level, a special problem is the limited authority, of drainage and sewerage authorities. For instance, small sewers are under the control of local and housing co-operatives, and emptying of septic tanks sometimes under a separate waste utility (if such exists). Such division of duties many hamper efficient and suitable management systems.

Poor enforcement of law and regulations

The legal system already provides reasonable means to the relevant authorities to take measures against pollution and potential risks to public health. In fact, laws, regulations and standards are partly too strict, in comparison with the existing situation in the country. It is impossible and unreasonable to enforce and apply all stipulations. This may, and most probably will, reduce the credibility of these and other regulations. The enforcement in general is still weak, probably due to transition from one system to another, relatively weak position of the enforcing ministries and agencies, and low priority give to environmental and sanitation issues when aiming at rapid economic growth.

Lack of sector data base

A major constraint for efficient sector development is the lack of centralised sector statistics, libraries and databases, where data and information would be freely available to all parties involved in the sector development. It is often very difficult to obtain adequate and consistent data, especially when data is required from agencies not directly controlled by the executing agency.

As an application of demand driven policy, emphasis in the institutional consideration of the proposed Strategy is in decentralisation of the activities from the central level to the local level, and from public sector to private sector. Decentralisation also creates new needs for central level and public sector involvement. They have to take measures to regulate and control the local and private sector activities.

3.6.2 Institutional arrangement

The institutional arrangements in the Philippines, Thailand and Vietnam are briefly described to illustrate the general and complex issues facing countries in this Region.

Philippine's Institutional Framework

In the Philippines, the most critical management issue for Metropolitan Waterworks and Sewer System (MWSS) is "inefficiency of organization and operation ". There are two fundamental causes for the inefficiency of the MWSS organization and operations. One is the monopoly of MWSS operations and the other is government regulations. In order to improve the overall efficiency of MWSS, the organization must be a transformed into a more responsive and accountable organization for consumers and other stakeholders through reform measures at various levels.

While many local government agencies have competent personnel and generic planning and management systems, they lack the experience necessary to carry out the statutory mandate of the Local Government Code; and to achieve the overall strategic objective of providing and managing sanitation and sewerage services without substantial support and direction by the National Government.

The multiple functions to be performed at the national level, even though actual service provision takes place at the local level, cut across the interests and jurisdictions of several existing agencies, whose continued interest in and promotion of the program are vital to its success. To provide the necessary energy, impetus, national-level coordination, and guidance and support of local activities, it is essential that a small unit be established in a national agency to manage the program. It is proposed that this unit be called the Central Sanitation and Sewerage Program Support Office (CPSO). It is further recommended that an interdepartmental advisory committee be formed to assist the CPSO in its efforts to coordinate the work of the national agencies that share responsibility for the support and approval of program activities.

Thailand's institutional framework

The current institutional framework for water pollution control is complicated as shown in Figure 3.1.

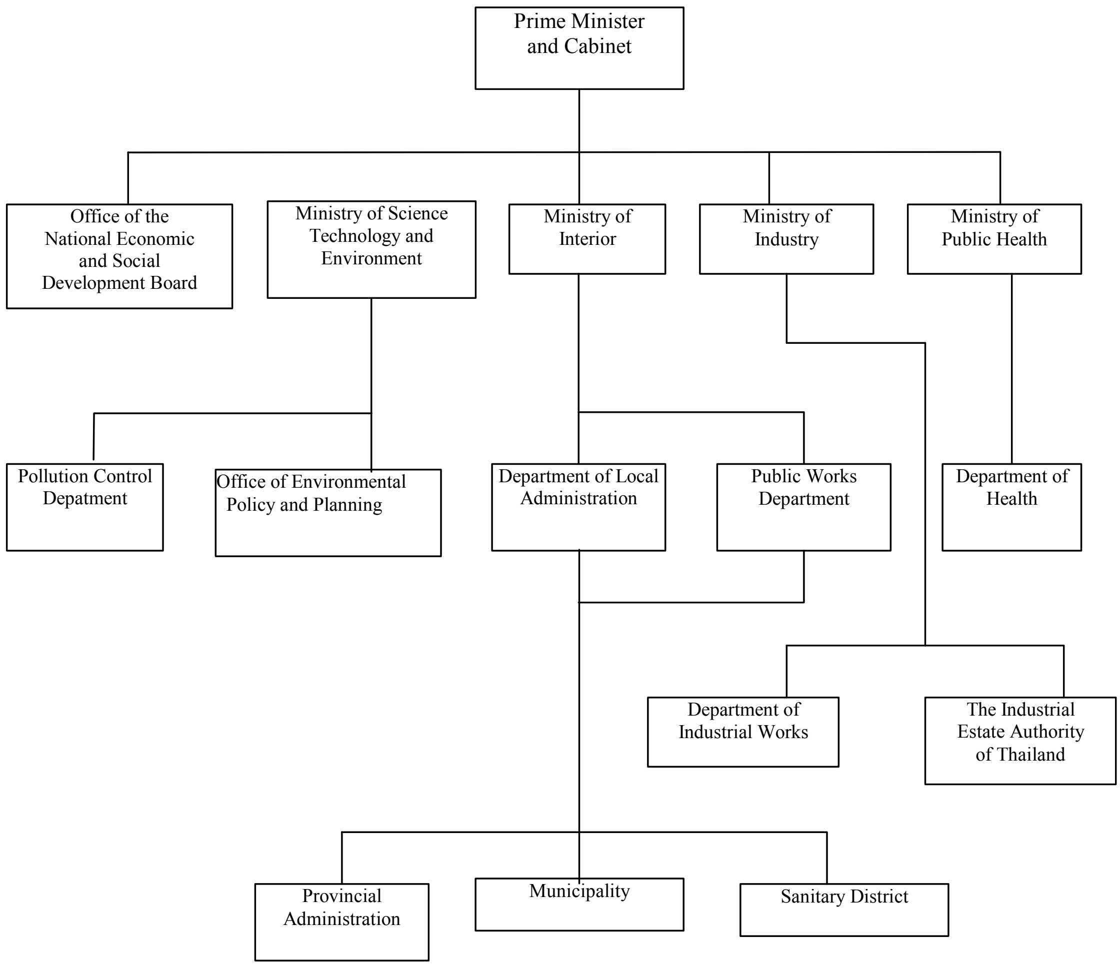

Figure 3.1: Thailand's current institutional framework for water pollution control.

Vietnam's institutional framework

Generally in Vietnam the sanitary drainage system is operated and maintained by public sanitation companies, although there are also a number of small road drainage channels owned and operated by the Transportation Department.

Current Institutional Framework in Halong

The upper strategy of the local government is composed of the Hai Phong People's Committee (HPPC), the elected People's Council and a number of departments and services that report both to the central government and HPPC. From the urban environmental investment point of view, the most important departments are the Department of Planning and Investment (DPI) reporting to the Ministry of Planning and Investment (MPI), which is the pivotal central government organisation controlling investments, and the Department of Investment and Development (DID) reporting to the Ministry of Finance. The department controls the flow of funds to investment projects and disbursement of funds borrowed from international development agencies, through the banking system, e.g. the bank of investment and development.

The Quang Ninh Transport and Urban Public Works Service (TUWS) is the umbrella organisation of some 26 public companies, which are divided in two main groups: state companies, which are autonomous and self-sustained, and public enterprises, i.e. companies not able to generate revenues enough to cover their costs and thus dependent on subsidies. In the former group TUWS acts as a monitoring agency only, but in the latter group TUWS is the channel of subsidy funds

Besides TUWS a number of HPPC's service and departments are also involved in reviewing and approving plans and proposals of sanitation sector organisations, such as:

- The construction service, which is the principal organisation in the construction sector, e.g. controlling a number of contracting and consulting companies. The Construction Service approves designs for construction works in investment projects.
- The Planning Institute is in charge of long and short term strategic planning and physical planning of the city. The Institute is responsible for the preparation of the Sewerage and Drainage Master Plan.
- The Department of Science, Technology and Environment is responsible for setting technical standards, promotion of new environmentally friendly technologies for production and for monitoring of compliance with environmental regulations.
- The Foreign Relations Office assists all projects receiving foreign support by arranging necessary clearances and simplifying procedures.
- The Quang Ninh Hygiene and Epidemiology Institute monitor the quality of water in rivers and lakes from a public health point of view.

Haiphong Urban Environment Company (URENCo)

URENCo, Previously Haiphong Sanitation Company, primarily concentrated on solid waste and wastewater management of the city.

The current organization of URENCo is seen in Figure 3.2. The organization consists mostly of Environmental Teams concerned with sewerage and drainage issues.

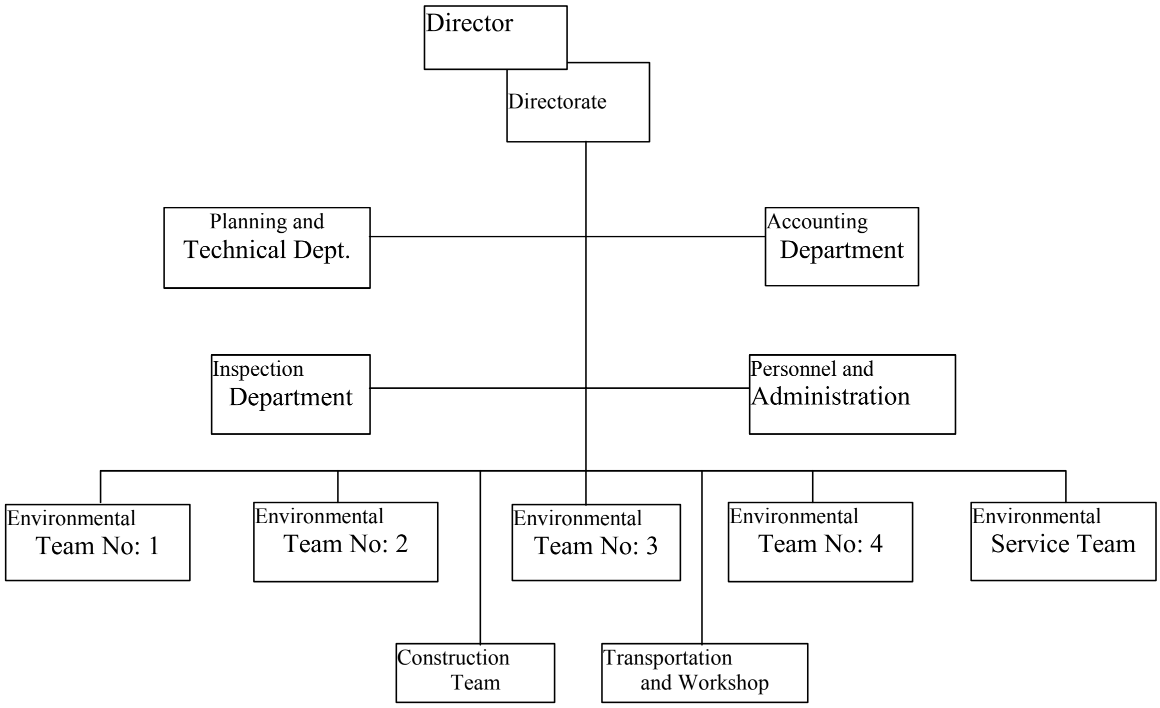

Figure 3.2: The current organization of URENCo

3.6.3 Policy framework

A number of major policies and programmes have been implemented by governments of the Asia and Pacific Region to address issues of environmental stress in urban and rural settlements. These include:

- urban development strategies;
- strengthening local government and involvement of NGOs;
- housing and services for the poor;
- urban land management, and
- resource mobilisation.

Typically throughout the region, national authorities are responsible for establishing environmental policy, and developing the appropriate legislation and standards for its implementation at local government level. As a result, provincial and state governments have been increasingly entrusted with carrying out environmental management, requiring considerable investment in planning, training staff and purchasing equipment. However, most local authorities throughout the developing countries are granted neither adequate financial resources nor adequate revenue raising powers by central government to carry out effective environmental management. Another major problem with this approach is that ultimately conflicts of interest will arise both within and between local authorities regarding the benefits of economic development versus environmental protection. With little or no accountability under law, this can lead to serious consequences for the environment.

Many governments of the region have placed high emphasis on mobilising community-based organisations and non-governmental organisations (NGOs) in a bid to strengthen environmental management at the local level. NGO programmes have proved to be particularly effective in areas such as public awareness and environmental education. Similarly, community participation is increasingly being encouraged during the planning process to ensure that environmental protection schemes are both appropriate and workable. Whilst the involvement of NGOs and community groups is still largely on an informal basis, some countries have made it mandatory with legislative provision. For instance, recent legislation in the Philippines requires involvement of NGOs and other private sector leaders in the committees that prepare local capital budgets (Kingly and Mikelsons, 1991). Informal co-operatives among low-income groups have also proved to be successful at managing local environmental resources.

NGOs have grown at an unprecedented rate in the last ten to fifteen years. With varying degrees of skill, they have shown that they can:

- reach poor populations unserved by other agencies;
- mobilise local resources and build local organisations:
- provide relatively low cost services to unserved populations;
- create innovative solutions to complex problems:
- organise networks of diverse organisations around shared visions: and
- act as intermediaries between governments and the community, serving to link communities to the wider political processes.

NGOs staffed with professional planners, architects, engineers and social workers have provided technical advice and helped co-ordinate numerous small-scale environmental projects in low-income countries. The famous Orangi Pilot Project provides a very good example, where the urban poor were provided with access to sanitation and drainage through innovative projects conceived by an NGO, and implemented through co-operative efforts by low income households in one community (ESCAP 1992).

With few exceptions, most governments in developing countries have largely avoided formulating urban land policies aimed at increasing the land access of low-income households. Responses towards this issue have largely been confined to actions such as subsidised housing for the poor, rather than addressing the underlying causes. Given that the overall task of extending urban water supply and sanitation services to the poor, which is going to be exacerbated by the increasing shift of the burden of poverty from rural areas to the urban centres, it is important that the fundamental question of land access and overcrowding is addressed in the near future.

3.7 Training (Topic g)

In the industrialised countries of the region, education levels of workers and management staff for wastewater are generally high. Schemes for training and human resource development at both national and local level are well founded and organised. Operators of the sewage and drainage system facilities are required to attend courses and pass certification examinations for promotion or to hold jobs. In addition to hands-on training on technology used in wastewater, staff at management level are often sent for further education. There are also regular promotional campaigns organised by government and NGOs to promote environmental protection.

In the developing countries, the various educational institutions have been offering courses in water supply and wastewater treatment design and operation for Engineers. Although there is training provided, these activities are severely limited by a lack of resources. There are inadequate funds for promotional campaigns and training by government and NGOs.

There are many activities related to training and human resources development that developing countries can experiment with. For example the National Strategy and Action Plan for Sanitation in the Philippines have been applied for a project in Metro Manila:

- Strengthen the ability of the planning and development coordination office staff in each target local government to develop community sewerage and sanitation plans.
- Conduct workshops for planning and engineering staff so that they understand the technical and financial options and "tradeoffs" that are part of any sanitation plan.
- Develop an institutional improvement plan for each target local government that identifies structures and staff skills needed to manage program functions.
- Assist each local government unit to establish a Program Management Unit (PMU) to carry out sanitation and sewerage program management functions.
- Liaise with human resources development task coordinators to institutionalize a long-term training and skills development mechanism to meet the future needs of the program.

Future action can be guided by the Asian Development Bank (ADBs) technical assistance and lending operations in its Developing Member Countries (DMC) for strengthening local government commitment to, and financing capacity for, urban environmental improvement. These actions include but are not limited to the following:

- Initiating policy dialogues with DMC as part of technical assistance lending operations;
- According priority urban water supply development and domestic wastewater, industrial waste management, including hazardous and toxic wastes;
- Stimulation demand for investment through institutional strengthening and pilot project that demonstrate the positive impacts of improved urban environment;
- Encouraging private sector participation, by assisting DMC in creating an environment conducive to investment;
- Enhancing the environmental benefits of other related urban sectors;
- Promoting regional co-operation and sharing of experience among ADB's DMC and;
- Increasing resource mobilisation to enhance financial and economic attractiveness of urban environmental improvement projects.

3.8 Public education (Topic h)

The strategy proposed in the National Strategy and Action Plan (Philippines National Urban Sewerage and sanitation Strategy feasibility studies Project) emphasises decentralisation of activities from the governmental to local level and promotes interaction between public and private sectors. In Vietnam, Ministry of Construction would be the leading sectoral organisation, i.e. responsible for sectoral policy and strategy formulation, sector planning preparation of guidelines, standards, codes of practices, co-ordination of human capacity building, research and development, financing mechanisms development and performance monitoring within the sector.

The utility agencies are advised to adopt more commercial approaches in their operations in parallel with the public sector’s efforts to gradually increase their autonomy. It is recommended that the agencies focus on key functions of utility management, such as establishment and management of capital-intensive sanitation systems, whereas the private sector could contribute in the secondary functions, such as maintenance of equipment, contracting of works, transportation, laboratory service etc. Gradual increase of cost recovery is pursued by introducing applicable tariff systems. A special financing facility is introduced which comprises a credit line (75 %) for capital intensive utility financing and revolving funds (25 %) for households or groups of households.

3.8.1 People's organizations and non-government organizations

Voluntary organizations are important allies in explaining the benefits of sanitation and promoting the national strategy and sanitation and sewerage programs, especially at the local level. A particularly important role for voluntary organizations is acting as intermediaries between local governments and squatters to help determine appropriate technologies for use in specific locations and the contributions to be made by users and those to be sought from local donors.

3.8.2 Schools

The Center Sanitation and Sewerage Program Support Office (CPSO) will develop educational programs aimed at school children with the cooperation of the Department of Health (DOH). The educational programs can utilize the results of the social research conducted for mass media purposes to put together an effective message on the benefits and effective use of sanitation improvements. It is recommended that the CPSO commission a pilot program in sanitation education that involves both teachers and children (NSAP 1994).

3.8.3 Person-to-person

Health education activities will include person-to-person contacts for the purpose of changing individuals' behaviour. In situations where there are no sanitary facilities (in many squatter slums), door-to-door field work may be required to make people aware of alternatives to the "wrap and throw" practice as well as to introduce possible programs for communal toilets and other sanitation services. Feedback from person-to-person contacts will enable the local governments to tailor community sanitation programs to address specific needs of residents.

If the sanitation and sewerage strategy is to succeed, it must first be adopted as a National Government policy and then be "sold" to National Government agencies, local government units, and individual consumers. The strategy represents a significant departure from past practice in several key areas, most importantly, in the way it allocates financial burdens. Other potential impediments, including the competition for resources and the lack of local government experience, will also require a national program to promote sanitation and sewerage as a means of improving health, protecting the environment and encouraging economic development.

Surveys conducted by the Consultant for willingness-to-pay in four urban areas revealed that many urban householders were unaware that health and sanitation problems were often caused by their own poorly functioning and overflowing septic tanks. The survey showed that most homeowners with flush toilets or pour-flush latrines felt "satisfied" with their current sanitation approach. This "micro" view of individual householders points out the challenge.

While removal of faeces from the immediate household is an important sanitation measure and one that the proposed strategy endorses, the health problems of the larger community cannot be solved as long as individual waste storage and disposal facilities are inadequate.

Nor will the contamination of rivers and shorelines be corrected if open sewers continue to discharge into waterways.

3.9 Financing (Topic i)

The problem of lack of central financing for environmental protection, is compounded in many of the developing cities of the region by the fact that, whilst they are extremely large, the vast majority of their population live in slums and squatter settlements and so do not make any contribution to the revenue base available to the city's administrators. The net result can be that those regions of a country which require the most funds for environmental management are the least able to raise them. However, in recent years there have been renewed efforts to devise mechanisms whereby the cities could be financially self-sustaining, primarily by involving the private sector in public utility management. This approach has proved to be effective in recovering operational costs, thereby raising funds for required infrastructure investment. Other steps taken by local authorities include generating revenue through sales and property taxes.

3.9.1 Financing source*s*

The financial mobilization and management program involves the development, approval and implementation of a revenue improvement plan for sanitation and sewerage. The strategic plan for each local government will identify how a local sanitation and sewerage program will be financed. The strategic plan will also establish a revenue improvement plan, focused presumably on those sources of funds which are deemed most important for program financing. Under the new Local Government Code, local government units have the authority to enact comprehensive revenue codes. While this may generate new, creative tax options in some jurisdictions, the following nine conventional sources of funds are the most likely means of financing a sanitation and sewerage program. It is recommended that national technical assistance and training efforts concentrate on these nine options:

Internal Revenue Allotment

- Special Levies.
- Development Fees.
    - Permit Fees.
    - Development Impact Fees.
    - Groundwater Protection Fees.
- Surplus Funds
- Sewerage Surcharges.
- Property Taxes
- Build-Operate - transfer/privatization
- Credit
- Other Private Sector Finance
    - Beneficiary Cash Contributions
    - Contributions in Kind
    - User Fees.

The above is a brief description for each of the sources of funds and its potential for contributing to the financing of a sanitation and sewerage program.

In Vietnam, locally funded investment projects are divided into three categories and their approval is sought from the relevant authority as follows:

1- Investments exceeding VND 200 billion (USD 16 million) are approved by the Prime Minister's Office.
2- Investments between VND 30 – 200 billion (USD 2.4 - 16 million) are approved by the relevant ministry upon authorisation from the Prime Minister's Office.
3- Investments which are less than VND 30 billion are approved by the People's Committee of the province.

Investments funded fully or partially from foreign sources in Haiphong should be submitted for the approval of the Prime Minister's Office, if the investment exceeds (USD) 5 million. All consulting assignments exceeding 1 billion Vietnam Dong (VND) 10 billion (USD 0.8 million) are approved by the Prime Minister's Office.

Within the city all investment projects, big or small, are subject to HPPC's approval. The authority of TUPWS to approve design and costs estimates of projects is limited to projects not exceeding VND 1 billion. For projects exceeding this limit endorsements of various service, e.g. the Construction Service, Financial Service, Land Administration Service, Department of Planning and Investment (DPI), Department of Investment and Development (DID) shall be sought prior to the approval of HPPC.

Tariff setting is also approved by HPPC after a clearance of the Tariff Committee comprised of representatives of the Financial Service, Department of Capital Fund Management. Service for Labour, Invalids and Social Welfare and TUPWS. The tariff is subject to endorsement of the People's Council before implementation by the decision of HPPC.

3.9.2 The problem in financing for developing countries

Lack of financial objectives and revenues

The ongoing restructuring of the economic aspect of the sewerage and sanitation sector has started slowly, and the target degree of the self-financing of utilities is still unclear. The officially accepted policy that the polluter pays, has not materialised, as yet. The government has showed little interest and attention to the sector requirement, and has taken only a few measures for overall improvement of the sector's operations and cost recovery. Therefore, clear and urgent decision making is about financial objectives, strategies and policies together with establishment of a sustainable base for the sector.

The tariffs for waste management and sewerage are too low or either totally missing in all the utilities in Vietnam. Only in Hanoi is there a surcharge levied on the water billings for drainage and sewerage cost coverage. The connections to public sewers are not charged at all, which has led to increasing government subsidies for operation and investment purposes. In those cases when a fee has been levied on a particular service, like sludge collection, resulting revenues are usually disproportionately low in relation to the cost of the service.

Low priority in budgetary allocations

In 1994, the share of water supply projects including sewerage and sanitation was about 5 % of the government's capital budget or VND 490 billion out of which the assumed portion of sewerage and sanitation is only 10 - 20 %. The central government has a strong control on local investments regardless of stated policies that underline decentralization of decision making and administration. Even where decision making was decentralised, local authorities have very limited financial potential for investment and knowledge to identify and negotiate external finance.

Due to the substantial and lengthy under investment, the physical facilities of utilities are often in poor condition and still wearing out without replacement, let alone new investment. Another factor contributing to high cost, low revenue operations is the poor standard of managerial skills and development held by Utility personnel relative to modern practice.

Constraints in funding availability

Apart from insufficient budgetary financing, the sector utilities have been unable to raise funding from other sources. Reasons are both structural and managerial. The financial market consists essentially only of four commercial banks which are now in transition, operating inefficiently and unable to extend long term loans for investment purposes. New and usually foreign supported banks and their branches are being established in increasing numbers but they are mainly for short term financing needs of high growth sectors like industry, commerce, tourism and foreign trade. Another structural constraint is that savings mobilisation in Vietnam is low and other specialised financing institutions like insurance companies and pension funds are either non-existent or unable to fill expanding need for long term finance.

As for management limitations, utilities themselves are not responsible for or experienced in raising foreign or local capital for investment. Instead, they have been awaiting help from local governments, which are dependent on central government funding and inexperienced in raising finance from alternative sources. As a result the sector has not succeeded in competing for foreign development assistance.

Poor financial management and low autonomy

Utilities' financial responsibilities are often limited to basic book-keeping and periodical reporting for government and statistical purposes, whereas the core financial function (such as tariff setting, staff remuneration, asset and depreciation management, capital budgeting, investment financial) have remained in the hands of urban and provincial authorities. Under these conditions, managers consider themselves as civil servants with limited initiative and motivation to improve the revenue base or cost efficiency of operations.

The present accountancy system does not fulfil management requirements and internal cost accounting and capital budgeting is either insufficient or non-existing. The large numbers of financial reports currently generated are mainly for the benefit of centralised planning, various authorities and statistical purposes. These deficiencies are also a serious obstacle for obtaining finance from international financing institutions and many other potential sources as well. To correct the situation, the Ministry of Finance introduced an accountancy reform in 1995 to be adopted by state owned enterprises. Its application to the sector utilities is also urgently required and a precondition for improved financial performance.

Financing of private sanitation

Traditionally, investment plans of government utilities have not included on-site needs, nor have financiers of the utilities included provisions or financial means for on-site purposes. In spite of it, households have upgraded their sanitation systems by relying on savings and borrowing from the informal financing sector and private lenders. The borrowing cost from private lenders is high (2-4% /month) and availability of finance is spasmodic.

Due to financial constraints, many of the households which prefer better sanitation conditions may not be able to improve their situation. Almost all the respondents in a socio-economic study answered that they prefer to pay by monthly installments rather than in a lump sum when installing improved sanitation systems. At the same time, respondents wanted to get financial support from the government to assist them in improving their sanitation facilities.

3.10 Information sources (Topic j)

Asian Development Bank

P.O. Box 789
Manila Central Post Office
0980 Manila
Philippines

Telephone: + 63-2-632-4444
Fax: + 63-2-636-2444
Email: adbhq@mail.asiandevbank.org
www@mail.asiandevbank.org
Contact: Dr. Shih-Liang Tu
Environmental specialist

Topics covered: a b c d e f g h j.

Description: The ADB is a regional development bank. It has 40 regional members from all parts of Asia, and 16 non-regional members from Europe and North America. The bank makes loans and equity investments for the economic and social advancement of Asian countries, provides technical assistance in the preparation and execution of development projects, and catalyzes investment of public and private capital for development purposes. Some of the Bank's projects have included MSWM.

Format of information:
Internet: http:/www.asiandevbank.org/
Language: English
Consulting or support services: Responds to requests for assistance in coordination development policies and plans.
Fees: some materials are distributed free and others at a low cost.

Asian Society for Environmental Protection

Rm B219, AIT Center
Asian Institute of Technology
GPO Box 2754
Bangkok 10501
Thailand

Telephone: +66 2 524 5245
Fax: +66 2 524 5236
Email: None
Contact: The Secretary General
Editor of ASEP Newsletter

Topics covered: a b c d e f g h

Description: ASEP is a nonprofit organization. It has many publications on environmental and waste management issues. The ASEP newsletter publishes newsworthy articles on environmental protection, including research or project summaries, news reports, notices of current and upcoming events, and other interesting and relevant as tiles about the environment.

Format of information: Newsletters, news reports and articles.
Internet: None
Language: Materials are available in English
Consulting or support services: Members of the Society provide consulting and supporting services.
Fees: Computer printouts are distributed free of charge; reports are at cost of reproduction or publication research services are at cost depending on technical and administrative requirements.

Department of Environment and Natural Resources - Philippines

DENR Building
Visaya Ave Diliman
Quezon City
Philippines

Telephone : +63 2 264 332
Fax: +63 2 922 6991
Email: rivera@copass.com.ph
Contact: Marcelino n. Rivera.JR
Sanitary Engineer IV

Topics covered: a b c e f h j.

Description: The Department sets policies, formulates plans, and disseminates environmental information to the public to enhance environmental awareness. Adopts and promulgates rule and regulations for environmental protect. Establish of management policies and quality standards for environment, with pollution control as one of it many aspects containing provision on air, water quality and land use management, natural resources management and conservation.
Format of information: Reports, pamphlets and guidebooks.
Internet: None
Language: Materials are available in Tagalog and English.
Consulting or support services: Provides technical supports to government agencies and local government.
Fees: None or at very low cost.

Development Technology Center of the Bandung Institute of Technology

Jalan Ganesha 17
Bandung 40132
Indonesia

Telephone : +62 22 250 3307
Fax : +62 22 250 1768
Email : dtcitb@ibm.net
Contact: Lanny T. Hardhy

Topics covered: a b c e f g h j.

Description: The Development Technology center of the Bandung Institute of Technology works on MSWM issues as part of its Village Technology Development Program. It runs courses on composting and encourages communities to start and maintain composting and other appropriate recycling practices. It also conducts experiments on recycling hardware technologies related to plastics, paper, and energy recovery. The center evaluates and monitors composting programs all over Indonesia, working with other NGOs under the aegis of Habitat, through the Metropolitan environmental Improvement Program (MEIP).

Format of information: Seminars, reports, pamphlets
Internet: Forthcoming
Language: Mainly Indonesian; English for international communication.
Consulting or support services: Consults on urban solid waste management and community development projects, and conducts workshops on experimental technology.
Fees: Usually negotiated.

Economic and Social Commission for Asia and the Pacific (ESCAP)

UN-Building
Bangkok 10200
Thailand

Telephone: +66 2 288 1600
Fax: +66 2 288 1097
Email: huset.unescap@un.org
Contact: Mr Jens Overgaard, Chief,
Human Settlements
Topics covered: a b c d e f g h j

Description: ESCAP is a UN agency that engages in all aspects of environmental control/conservation, urban environmental management, and environmental education. It works closely with government agencies dealing with the environment and waste management services. It provides funding and expertise in activities related to the environment.

Format of information: Reports, proceedings, environmental guidelines and standards, and materials for skill development and education.
Internet: None
Language: Materials are available in many languages.
Consulting or support services: Provides funds and technical support services to member nations. Also maintains library facilities.
Fees: Materials are distributed free, with some postage charges.

ENSIC (Environmental Systems Information Center)

Asian Institute of Technology
PO Box 4
Klong Luang
Thailand

Telephone: +66 2 524-5863
Fax: +66 2 524-5870
Email: enreric@ait.ac.th
Contact: Mrs. Lilia R. Austraco, Manager,
Information Centers.

Topics covered: a b c d e f g h

Description: ENSIC facilitates the dissemination, evaluation and discussion of research, case studies, and field experiments related to environmental policy, management, and engineering. Issues covered include solid waste, wastewater, hazardous waste, air and noise pollution, soil pollution, land management, water supply, clean technology, biological resources management, health and sanitation, environmental impact assessment, and environmental economics. The organization publishes a newsletter about these issues, covering both technical and regulatory matters.

Format of information: Technical reports and papers, manuals, guidebooks, newsletter.
Internet:
http://www.ait.ac.th/clair/centers/ensic.html
Language: Materials are in English
Consulting or support services: AIT undertakes contract research and consulting services.
Fees: ENSIC membership rates are US$ 130 for institutions and US$ 80 for individuals.

Environmental Impact Management Agency (BAPEDAL) - Indonesia

11 Floor, Jalan Jenderal Sudirman # 2
Jakarta
Indonesia

Telephone: +62 21 570 3419
Fax : +62 21 583 918
Email: None
Contact: Ms Masnellyerti Hilman, Director,
Hazardous Waste Management

Topics covered: f h j

Description: The Agency develops policies, for mullets regulations and laws, reviews existing laws and regulations, and recommends amendments whenever necessary. It also disseminates information on environmental conservation, pollution control, and issues of waste management.

Format of information: Books, reports, code of practice, and materials for human resources development.
Internet: None
Language: Materials are mainly in Indonesian with some editions in others languages.
Consulting or support services: Provides technical support services to government agencies, businesses and the communities.
Fees : Materials are distributed free or at low cost.

Environmental Protection Agency Australia

10 Blackall Street
Barton, ACT 260
Australia

Telephone: +61 6 274 1498
Fax: +61 6 274 1230
Email: epag@cepa.erin.gov.au
Contact: Mr Mark Hyman, Asst Secretary

Topics Covered: a e f g h j

Description: The waste management Branch of the Australian EPA implements the National Waste Minimization and Recycling Strategy, regulates the dumping of waste at sea, works to minimize the pollution of the marine environment from shipping activities, and regulates the import and export of hazardous waste. It is establishing the National Pollutant Inventory, participating in the development of management plans for the disposal of scheduled waste, and promoting redemption of contaminated sites. Under the National Waste Minimization and Recycling Strategy established in 1992, the Federal Government, together with the state and territory governments, has developed a range of initiatives that will help achieve the national target for the reduction of waste going to landfills by 50% by 2000, based on 1990 per-capita levels.

Format of information: Reports, guidebooks and materials on waste minimization, recycling, and reuse.
Internet:
http:// www.erin.gov.au/portfolio/epa/epa.html
The Waste management Branch of EPA is at
http://www.erin.gov.au/portfolio/epa/waste_man.html.
Language: English
Consulting or support services: The Environmental Resources Office Scheme of the Agency provides officers in each state and territory Local Government Association to deal specifically with waste matters.
Fees: Materials are distributed free or at low cost.

Global Environment Centre Foundation (GEC)

2-110 Ryokuchi-koen
Tsurumi-ku
Osaka 538
Japan

Telephone: +81-6-915-4121
Fax: +81-6-915-0181
Email: gec@unep.or.jp
Contact: Prof. Nobuaki Kumagai, President

Topics Covered: a c d e g h i

Description: The Global Environment Centre Foundation (GEC) is a nonprofit organization that supports the Osaka Office of UNEP's International Environmental Technology Centre (IETC). It also collects and disseminates information on environmentally sound technologies for MSWM and other fields related to the environment. The center has constructed a searchable database on environmental technology within its World Wide Web site. Listings of technical information sources are also provided through the Internet. A list of specialists in several environmental fields is available for those seeking such advice.

Format of information: Reports, newsletters
Internet: Summaries of about 160 Japanese solid waste treatment technologies are provided on the Environmental Technology Database at http://www.unep.or.jp/gec/
Language: English and Japanese
Consulting or support services: Provides technical information upon request.
Fees: None

Hanoi Sewerage Drainage company

8 Van ho
Hanoi
Vietnam

Telephone: +84 49 762245
Fax: +84 49 762663
Email: urencohn@netnam.org.vn
Contact: Le minh Chau, Director

Topics Covered: a b f h e

Description: HDSC is agency responsible for the implementation and operation and maintenance of the drainage and sewerage system. Reviews and amends the existing environmental framework whenever necessary. It recommends and provides fiscal instruments for pollution abatement and to improve environmental management capacity in government, the private sector, and in communities.
Format of information: Reports, books, technical papers, newsletters, manuals, and handbooks.
Internet: None
Language: Mainly in Vietnamese, with some publications in other languages.
Consulting or support services: It undertakes contract construction, operation and maintenance sewage system.
Fees: None or at very low cost.

Hanoi Urban Environment Company (URENCO)

18 Cao Ba Quat Street
Hanoi
Vietnam

Telephone: +84 4 823 0062
Fax: +84 4 823 2566
Email: None
Contact: Nguyen Duc Hoa
Deputy Director

Topics Covered: a b c e f g h j

Description: URENCO deals with all aspects of MSWM services, focusing on Hanoi. It carries out collection, transfer, and disposal of MSW and special wastes such as construction/demolition debris and hospital wastes. It supervises the picking of recyclable from MSW by waste pickers, and operates and maintains landfills and composting facilities. URENCO also sets guidelines and provides skill development for MSWM personnel.

Format of information: Reports, guidebooks, and pamphlets.
Internet: None
Language: Materials are mainly in Vietnamese.
Consulting or support services: Undertakes contract MSWM services.
Fees: Materials are available at cost.

International Environmental Planning Center (INTEP)

Dept. of Urban Engineering
University of Tokyo
7-3-1, Hongo, Bunkyo-ku
Tokyo 113
Japan

Telephone: +81-3-5800-5948
Fax: +81-3-5802-2956
Email: kitawaki@env1st.t.u-tokyo.ac.jp
Contact: Prof.Hidetoshi Kitawaki

Topics Covered: a b c e f g h j

Description: As part of the Department of Urban Engineering at the University of Tokyo, INTEP is primarily responsible for the education of students and for research in water supply and sanitation related to developing countries. The development of planing methodologies is another of the center's priority areas of research. In addition, INTEP serves as an information center active in information exchange on appropriate technology. The center publishes a newsletter in English to disseminate information from Japan to other countries; the Japanese version is meant to do the reverse. INTEP carries out its field research activities mainly in Indonesia, Vietnam, and Bangladesh. In Vietnam, INTEP is developing a political simple composting system at a landfill site.

Format of information: Publications are in paper format.
Internet: http://www.urban.rcast.u-tokyo.ac.jp/due/kitawakilab/intep.html
Language: English and Japanese
Consulting or support services: INTEP provides voluntary consulting and support services.
Fees: None

Korea Advanced Institute of Science and Technology (KAIST)

Cheongryang
P O Box 131
Seoul
Republic of Korea

Telephone: +82 2 963 0392
Fax: +82 2 969 0230
Email: NA
Contact: Dr Kyu-Hong Ann, Head, Enviironment System Group
Also : Dr Hang-Sik Shin, Chanirman, Civil Engineering,
Tel : + 82 2 967 0121 / 966 1931/ 7

Topics Covered: a c d e f h j

Description: KAIST is an academic and research institute. It carries out R&D projects in waste management and environmental pollution and conservation in general. The Institute undertakes contract research and constancy for the industry and government agencies. It helps formulate plans, policy, and strategies on environmental management and initiates technology transfer, education, and training programs.

Format of information: Reports, books, technical papers, journals, newsletters and manuals.
Internet: None
Language: Materials are mainly in Korean with some in English and other languages.
Consulting or support services: It undertakes contract R&D projects and provides technical support services to businesses and government agencies.
Fees: None or at very low cost. (US$ to 20)

Local Water Utilities Administration.

Katipunan Road
Balara, Quezon cities
Philippines.
Telephone: +63 2 929 6107
Fax: +63 2 922 3434
Email: LWUA@MOZOCOM.com
Contact: Dr.Raynaldo B.vea
General Director

Topics Covered: a b e f g h j

Description: LWUA is already responsible for the support local water districts with program somewhat similar to those proposed for local sanitation and sewer. This experience can be used immediate advantage to initiate national program operations efficiently and assist local government in establishing strategies and manage plans. That function related to sanitation and sewerage.

Format of information: Reports, code of practice, manuals, and guidebooks.
Internet: None
Language: English.
Consulting or support services: Gives technical advice to government agencies.
Fees: None.

Manila Waste Sewer System.

Katipunan Road
Balara, Quezon cities
Philippines.

Telephone: +63 2 922 3757
Fax: +63 2 921 2887
Email: MWSSrvea@info.com.ph
Contact: Dr.Raynaldo B.vea
General Director

Topics Covered: a b e f g h

Description: The most critical management for MWSS is "inefficiency of organization operations". One is monopoly of MWSS operations and the other is government regulation. MWSS shall own the entire assets of infrastructure from sourcing through treatment and transmission to distribution in the Manila Areas.

Format of information: Reports, code of practice, manuals, and guidebooks.
Internet: None
Language: English.
Consulting or support services: Gives technical advice to government agencies.
Fees: None.

Ministry of Construction - China

Department of Science and Technology
9 San Li He Road
Beijing100835
People's Republic of China

Telephone: +86-10-6839 3219
Fax: +86-10-6839 4530
Email: dostmoc@public2.bta.net.cn
Contact: Nie Miesheng

Topics Covered: a b c d e

Description: The Department is a government body responsible for management of scientific research and technology development on urban solid waste and waste water treatment.

Format of information: Technical reports and scientific/technical papers in local and international journals.

Internet: None
Language: Materials are available mainly in Chinese.
Consulting or support services: The Department provides consulting and support services to municipalities and other government bodies.
Fees: Depend on project and are often very low.

Ministry of Construction - Vietnam

Vietnam consultant on water supply sanitation and environmental
5 Duong Thanh Street
Hanoi
Vietnam

Telephone: +84 48 244328
Fax: +84 48 284760
Email: viwase@hn.vn
Contact: Dr. Nguyen Nhu Ha, General Director

Topics Covered: a b c d e

Description: The Company is a government body responsible for management of scientific research, technology and consultant on the water supply, solid waste and waste water treatment.

Format of information: Technical reports and scientific/technical papers in local and international journals.
Internet: None
Language: Materials are available mainly in Vietnam.
Consulting or support services: The Company provides consulting and support services to municipalities and other government bodies.
Fees: Depend on project and are often very low.

Ministry of Public Works - Indonesia

Jalan Raden Patah T/1
Annex Building, 2nd Floor
Keb Baru, Jakarta 12110
Indonesia

Telephone: +62 21 739 7792
Fax: +62 21 739 7792
Email: None
Contact: Ir Dr Darmawan Saleh, Director of Directorate of Environmental Sanitation and Director General of Directorate of Human Settlement

Topics Covered: a b e f g h j
Description: The Department is a government body responsible for the planning, development, and administration of infrastructure and public amenities. The Directorates of Environmental Sanitation and General Human Settlement (a) study and assess development projects subject to environmental impact assessment, (b) evaluate the site suitability and effectiveness of pollution control systems for projects, (c) provide environmental input to development agencies, and (d) carry out enforcement on pollution sources and review the existing regulations and recommend new ones where necessary. The Directorates also disseminate environmental information to the public to enhance environmental awareness.

Format of information: Reports, pamphlets, code of practice, regulations, and human resource development guidebooks and manuals.
Internet: None
Language: Materials are mainly in Indonesian with some in English and other languages.
Consulting or support services: They give technical advice and expertise to local authorities and other government agencies.
Fees: Materials are distributed free to government bodies and libraries in Indonesia and some are available to the public at low cost.

Ministry of Science, Technology and Environment - Thailand

60/1 Soi Phibun Wattana 7
Rama VI Road
Bangkok 10400
Thailand

Telephone: +66 2 279 0129
Fax: +66 2 279 0672
+66 2 246 8016
Email: None
Contact: Dr. Pakit Kisaranit, Director General of Pollution Control Department

Topics Covered: a c d e f h i j

Description: The Ministry proposes and enforces environmental laws and regulations, develops national networks of monitoring systems, and disseminates environmental information to the public to enhance environmental awareness and education. It provides funds and trainers for various projects and educational activities.

Format of information: Reports, code of practice, laws and regulations, pamphlets, manuals and guidebooks for training and public education
Internet: None
Language: Materials are mainly in Thai. Editions in English and other languages may be available.
Consulting or support services: The Ministry provides technical support services to local authorities and other government agencies.
Fees: None

Ministry of State for Population and the Environment - Indonesia

15 B Jalan Merdeka Barat
Jakarta 10110
Indonesia

Telephone: +62 21 374 563
Fax: +62 21 385 7578
Email: None
Contact: Mr M S Kismadi, Special Assistant

Topics Covered: a f h j

Description: The Ministry formulates policies, promulgates laws and regulations, and reviews and amends the existing environmental framework whenever necessary. It recommends and provides fiscal instruments for pollution abatement and to improve environmental management capacity in government, the private sector, and in communities.

Format of information: Laws and regulations, code of practice, reports, guidebooks, pamphlets, and information fact sheets on environment and waste management.
Internet: None
Language: Materials are mainly in Indonesian with some editions in English and other languages.
Consulting or support services: Provides fund and technical support services to government agencies and the communities.
Fees: Materials are available free or at very low cost.

National Centre for Scientific Research of Vietnam

Nghia do,
Tu liem
Hanoi
Vietnam

Telephone: +84 47 562763
Fax: +84 48 354076
Email: None
Contact: Pham van Luc
Leader of the Environment Department

Topics Covered: a c f h i

Description: The Centre is a government body involved in research and development on various issues, including waste management. It helps formulate facilities plans and monitoring systems. It advises government bodies on environmental management issues and policy.

Format of information: Reports, books, technical papers, newsletters, manuals, and handbooks.
Internet: None
Language: Mainly in Vietnamese, with some publications in other languages.
Consulting or support services: It undertakes contract R&D projects and provides technical support services to government bodies.
Fees: None or at very low cost.

National Environmental Protection Agency - China

Department of Pollution Control
115 Xizhimennei Nanxiaojie
Beijing 100035
People's Republic of China

Telephone: +86 10 661 51937
Fax: +86 10 661 51762
Email: None
Contact: Mr Hu Shouren, Division Chief of Solid Waste Management

Topics Covered: a b c d e f g h j

Description: The Department of Pollution of the National Environmental Protection Agency is involved in all aspects of pollution control including solid waste management. The agency is responsible for strategic planning, development of legislation for specific environmental issues, applied research for application in relevant areas of environmental management, and environmental monitoring and planning. It is also involved in the development of waste disposal facilities. The department carries out enforcement on pollution sources to ensure that emissions/discharge meet standards and criteria. The agency Publishes reports, laws and regulations on pollution control, code of practice, and manuals and materials for training and human resources development and public education.

Format of information: Reports, handbooks, manuals, code of practice on specific topics.
Internet: None
Language: All materials are in Chinese but there are editions in other languages.
Consulting or support services: Provides technical support services to various government bodies.
Fees: Materials are free or available at very low cost.

National Environmental Protection Agency - Vietnam

67 Nguyen Du
Hanoi
Vietnam

Telephone: +84 48 223194
Fax: +84 48 223194
Email:
Contact: Nguyen Ngoc Sinh Director

Topics Covered: a b c d e f g h j

Description: The Department of Pollution of the National Environmental Protection Agency is involved in all aspects of pollution control including solid waste management. The agency is responsible for strategic planning, development of legislation for specific environmental issues, applied research for application in relevant areas of environmental management, and environmental monitoring and planning. It is also involved in the development of waste disposal facilities. The department carries out enforcement on pollution sources to ensure that emissions/discharge meet standards and criteria. The agency Publishes reports, laws and regulations on pollution control, code of practice, and manuals and materials for training and human resources development and public education.

Format of information: Reports, handbooks, manuals, code of practice on specific topics.
Internet: None
Language: All materials are in Chinese but there are editions in other languages.
Consulting or support services: Provides technical support services to various government bodies.
Fees: Materials are free or available at very low cost.

National Institute of Environmental Research - Korea

Domestic Waste Division
Waste Management Research Department
613-2 Bulkwang-Dong, sunpyug-Gu
Seoul 12-040
Republic of Korea

Telephone: +82 2 389 8724
Fax: +82 2 358 2961
Email: None
Contact: Dr Yoo-Won Lee, Director

Topics Covered: a b e f g

Description: NIER is a research organization involved in all aspects of environmental studies. Its Waste Management Research Department initiates programs, in-house and with other organizations, of basic and applied research and development into relevant areas of waste management, environmental monitoring, and assessment. The Department carries out R&D projects on domestic waste management covering waste minimization, recycling, reuse, collection and transfer, landfill, and special wastes.
Format of information: Results are published in book form. The Department also publishes training guides and manuals for technology transfer and pamphlets on wastes management for public education.

Internet: None
Language: Materials are mainly in Korean with some in other language.
Consulting or support services: The Department undertakes contracts R&D and consultant projects.
Fees: materials are available at a low cost.

Policy and Planning Department Thailand

Division of Infrastructure and Environment
Bangkok Metropolitan City Hall
Bangkok 10200
Thailand

Telephone: +66 2 224 2978
+66 2 224 4683
Fax: +66 2 225 7947
+66 2 224 2988
Email: None
Contact: Dr-Ing Ksemsan Suwarnarat,
Mr. Chanchai Pavasuthikam

Topics Covered: a b c d e f h i

Description: The Department formulates policies, plans, and strategies for waste management. It evaluates and carries out R&D in relevant areas of environmental management, monitoring, and control. It plans waste disposal facilities, code of practice, and programs for human resource development.

Format of information: Reports, handbooks, manuals, and code of practice on specific issues.
Internet: None
Language: Materials are mainly in Thai with a few in other languages.
Consulting or support services: Provides technical supporting service to municipalities and government bodies.
Fees: None or at very low cost.

Project Management Office (PMO) President's Task Force on Waste Management

Environmental Management Bureau - DENR
Topaz Building, 99-101 Kamias Road
Quezon City
Philippines
Telephone: +63 2 928 3711
Fax: +63 2 975 698
Email: None
Contact: Mr Albert A Magalang, Head

Topics Covered: a b c d e f g h j

Description: The PMO of the President's Task Force on waste management is responsible for policy formulation related to materials recovery, provision of technical assistance in designing transfer stations, studying centralized composting and anaerobic digestion facilities, performing technical evaluation of MSW incinerators, provision of technical assistance on the design and site identification of MSW landfills, and enhancing MSW related skill development and public education.

Format of information: Reports, technical papers, rules and regulations, and materials for human resources development.
Internet: None
Language: Materials are mainly in English and the national language.
Consulting or support services: Provides technical support services to municipalities and government agencies and NGOs.
Fees: None, except mailing cost.

South Pacific Regional Environment Programmer (SPREP)

PO Box 240 Apia
Western Samoa

Telephone:	+685 21929
Fax:	+685 20231
Email:	sprep@pactok.peg.apc.org
Contact:	Andrew Munro, Waste Management & Pollution Prevention Officer

Topics Covered: a b c d e f g h

Description: SPREP provides technical assistance in environmental management to its member states, the countries of the South Pacific region. MSWM assistance is provided through the South Pacific Regional Pollution Prevention, Waste Minimization and management Programs. SPREP relies on donor financing for the implementation of its programs and interacts extensively with many other organizations, including WHO, SOPAC, South Pacific Forum Secretariat, European Union, and the Governments of Australia, France, New Zealand, and Canada.

Format of information: Publications can be provided in both paper and disk format.
Internet: limited connectivity
Language: English and French
Consulting or support services: Provides technical assistance directly to its member governments.
Fees: Publications are usually distributed free of charge.

UNEP International Environmental Technology Centre (IETC)

Osaka Office
2-110 Ryokuchi-koen
Tsurumi-ku
Osaka 538
Japan

Telephone:	+81-6-915-4580
Fax:	+81-6-915-0304
Email:	hshiroi@unep.or.jp
Contact:	Ms. Lilia Casanova, Deputy Director

Topics Covered: g h j

Description: UNEP's International Environmental Technology Center (IETC), the publisher of this Source Book, was inaugurated in April 1994 to provide a unique contribution in promoting environmentally sound technologies (ESTs), including their transfer and utilization. The Centre is now constructing its own database covering ESTs with the assistance of the Global Environment Center Foundation (GEC) and the International Lake Environment Committee (ILEC), both Japanese supporting organizations to IETC.
In 1995, UNEP-IETC, in collaboration with UNEP Industry and Environment/PAC (Paris) and INFOTERRA (Nairobi), undertook a survey of 400 organizations involved in EST information dissemination. A report to the Commission on Sustainable Development (CSD) on this survey has recently been prepared which identifies 84 EST related information systems. IETS's site on the World Wide Web provides an extensive list of EST information sources, which covers institutions worldwide.

Format of information: Reports, newsletters, training materials

Internet: http://www.unep.or.jp
Language: English
Consulting or support services: Provides advisory services to selected locations though joint activities known as the "Sustainable Cities Programs" with UNCHS (Habitat).
Fees: None

United Nations Centre for Regional Development (UNCRD)

1-47-1 Nagono, Nakamura-ku
Nagoya 450
Japan

Telephone: +81-52-5619378
Fax: +81-52-5619374
Email: 45438u@nucc.cc. nagoya-u.ac.jp
afernand@uncrd.or.jp
Contact: Antonio L. Fernandez

Topics Covered: a h j

Description: UNCRD is a research and training institution dealing with regional (sub national) and urban development planning. Beginning in 1987, it conducted a research project on the "Improvement of Solid Waste Management in the Context of Metropolitan Management in the Asian Countries". Presently, MSWM-related activities are linked with a project on urban environmental management. UNCRD has held meetings on different aspects of MSWM-financial, institutional, citizen participation, recycling, partnerships-in cooperation with government institutions in China, Indonesia, Japan, Malaysia, and the Philippines.
On the basis of collaborative research with local officials and universities, UNCRD has published papers in its journal, "Regional Development Studies". The Center also disseminates MSWM information in developing countries via its newsletter, "SWM Info" and includes MSWM topics in its International Training Course in Regional Development Planning, held April-May each year.

Format of information: Publications are in paper format.
Internet: Forthcoming:
http://www.zeus.uncrd.or.jp/index.htm
http://zeus.uncrd.or.jp/index.htm
Language: English and Japanese
Consulting or support services: Requests for training and collaborative research from public institutions and technical cooperation agencies may be addressed to the Director.
Fees: Most publication are distributed free, although some must be purchased. The "Research Report Series" is also available. UNCRD also exchanges publications with others.

3.11 Case studies (Topic k)

3.11.1 The study on urban drainage and wastewater disposal system in Hanoi

Study Period : October 29,1993-February 28,1995
Counterpart Agency : Hanoi People's Committee
Socialist Republic of Viet Nam

Background

Hanoi is the capital city of Viet Nam, which is the political, economic, and cultural center of the country. The Government of Viet Nam (GOV) has long been keen to improve the drainage and wastewater disposal systems as quickly as possible in order to sustain Hanoi's economic growth and hygienic improvement.

Existing drainage and wastewater disposal systems are falling into a state of disrepair and their conveyance capacities are being reduced (Photo 3.1). This results in frequent flooding of the urban area and deterioration of water quality in rivers and lakes of the surrounding areas. These have been creating serious problems for the environment and have hampered economic development activities. In recent years, several peripheral areas have been subject to rapid population increase and development without provision of adequate drainage and wastewater disposal systems. This further aggravates the problems (Photos 3.2).

Photo 3.1: Kimnguu River

Photo 3.2: Yenmy Village

Objective

The Study's objectives are: (1) to formulate a master plan (target year: 2005) on urban drainage and wastewater disposal systems in the central part of Hanoi City (almost 135km^2) and (2) to conduct a feasibility study (F/S) on urban drainage systems and/or wastewater systems for the prioritized projects selected in the master plan.

Study area

The Study Area comprises the central part of Hanoi City (the existing urbanized area and its adjacent areas), which is surrounded by the Red River (in the north and east), the Nhue River (in the West), and the old To Lich River (in the south). The area occupies about 135 km^2 (including the West Lake) while the total area of Hanoi City is 925km^2.

Outline of the proposed plans

Basic policy

In the formulation of this drainage/sewerage master plan (Master Plan), primary attention shall be paid to coordination with the City Master Development Plan. A phased implementation plan of the drainage/sewerage projects shall be proposed considering the suitable scale of each project in ensuring viability of the projects proposed in the Master Plan.

From these viewpoints, the Master Plan mainly consists of two projects, the Drainage Project and the Wastewater Disposal Project. Both projects are scheduled to be implemented in stages until the year 2020.

Of the plans examined in the Master Plan, a priority project for the feasibility study was selected in consideration of the specific aspects such as needs and technical requirements for each district.

Outline of the priority project

The To Lich River Basin drainage Project (the Project) has been selected as the priority project for implementation because this project has the highest economic viability among the plans examined in the master plan study and proves to be beneficial in improving people's livelihood and hygienic conditions. The outline of the Project is shown in Table 3.17.

Table 3.17: Outline of the Project

Work Components	1st Stage Construction (1995-2000)	2nd Stage Construction (2000-2004)
(a) Yen So Pumping Station		
(Total Pumping Capacity: 90m^3/s)	45m^3/s	45 m^3/s
(b) Regulating Reservoir		
(Reservoir Capacity: 5.19million m^3)	3.87 million m^3	1.32 million m^3
(c) River Improvement		
(Improvement Length: 33km)	33km	-
(d) Drainage Channels (Total Length:30.8km)		
- Removal of sediments (as an urgent project)	30.8km	-
- Establishment of channel sections	-	30.8km
(e) Floodgates and Control Gates (7places)	7places	-
(f) Bridges and Culverts : 125 places	96 places	29 places
(g) Lake Drainage/ Conservation		
Dredging Works: 18lakes	4lakes	14 lakes
Conservation Works: 11lakes	-	11lakes
(h) Sewer Network		
- Removal of sediment: Total Length 120km (as an urgent project)	120km	-
- Addition/new installation of pipes: 225km	35km	190km
- Addition/new installation of culverts: 116 x 10^3 (spatial volume)	22 x 10^3m^3	94 x 10^3 m^3

Project cost

This Study aimed to prepare a master plan up until the year 2010, following the original scope of works. However, the result of a preliminary review showed that all the plans cannot be completed within 15 years due mainly to financial constraints. Accordingly, the implementation period will be extended up to the year 2020.

The implementation costs of major projects (structural measures) proposed in the master Plan were estimated at about US$ 1,162 million equivalent (Dong 12,550 billion, 1994 base price). The fund requirement for the implementation is shown in Table 3.18.

Table 3.18: Fund required for the implementation of plans

Plans	1995-2000	2001-2005	2006-2010 (Yearly Average)	2010-2015	2016-2020	Grand Total
Drainage Plan	28.6	36.1	26.1	7.1	-	524.1
Wastewater Disposal Plan	4.7	25.8	32.1	32.3	31.9	637.9
Total	35.3	61.9	58.2	39.4	31.9	1,162.0

Evaluation

The proposed drainage and wastewater disposal plans were proved to be economically, financially, technically, and environmentally viable. The To Lich River Basin Drainage Project, selected as the priority project, aims to improve flood control and drainage, and is also evaluated as improving residential environment, living standards, and urban transportation systems.

Economic evaluation

The benefits of a drainage project and a wastewater disposal project relate to each other. However, the Study assumes that the reduction in flood damage is the benefit of the drainage project, and the improvement of hygienic conditions, including the increase of land value, is the benefit of the wastewater disposal project. The economic evaluation indexes were assessed in comparison of the benefits and the costs of projects as shown in Table 3.19.

Table 3.19: Result of economic evaluation

Project	Cost (US$ x 10^6 equiv.)		Annual	EIRR
	Financial Cost	Economic Cost	Benefit (US$ x10^6 equiv.)	(%)
Drainage Plan				
A) To Lich River Basin Drainage Plan	3174	285.7	12.6	11.6
- 1st Stage	160.4	146.8	7.6	11.7
- 2nd Stage	157.0	138.9	5.0	11.4
B) Nhue River Basin Drainage Plan	206.7	174.8	2.7	9.3
Total	524.1	460.5	15.2	10.9
Wastewater Disposal Plan				
A) Centralized Treatment System	567.1	523.4	63.4	5.2
B) On site Treatment System	70.8	66.1	6.1	-
Total	637.9	589.5	69.5	5.2

In general, the drainage plan is economically viable, taking into account its Economic Internal Rate of Return (EIRR) of more than 10%. For the on-site treatment system in the wastewater disposal plan, a negative EIRR value was obtained. However, the plan should be assessed overall in view of the necessity of improving the hygienic environment of Hanoi City as a whole. The overall EIRR of 5.2% is fairly adequate to justify the plan as viable for a sewerage project.

Financial analysis

The projection of financial resources was attempted on a premise that national budget would increase almost in proportion to the Gross Domestic Product (GDP) growth rate (10-12%/year) and accordingly the Hanoi development expenditures would also increase. The projected figures are shown in Table 3.20 below.

Table 3.20: Projection of Hanoi's development expenditures

Item	2000	2005	2010
Hanoi Total Development Expenditures	343	635	1,081
Allocation to Drainage/Sewerage Sector	34	64	130

(Unit: US$ million equiv.)

The required fund for the implementation of the plans proposed in the Master Plan, estimated in Table 3.19, is generally within the range of the budgetary resources projected in the above table, though there may be some surplus or shortage each year. Hence, the proposed implementation plan is deemed to be practical.

Environmental impact assessment

Drainage and sewerage development, in particular the latter, aims at improving living standards and water quality, and hence is regarded to be the development which would improve the city's environment (Photo 3.3). The plans formulated in the Master Plan are in general in line with this concept and will not cause any particular environmental problems.

Photo 3.3: Kimnguu River under construction

Overall, the To Lich River Basin Drainage Project will contribute to the improvement of the City's environmental conditions. Flood inundation results in economic loss the people, and is also one of the main factors aggravation hygienic conditions, which would be mitigated by the Project. The improvement of river and lake facilities will result in the improvement of people's living environment.

Recommendations

- The Sewerage and Drainage Company (SDC) is the most important agency responsible for the implementation and operation and maintenance of the drainage and sewerage projects. Its functions shall be strengthened by providing of sufficient O&M budget, reinforcing middle to senior class engineers, and training technicians.
- A new organization for the implementation of the To Lich River Basin Drainage Project shall be established in order to discuss and determine all collaborations required to lead the Project to a successful completion, both for management and technical guidance.
- Comprehensive environmental survey data have not been accumulated at present. It is recommended that an "Environmental Monitoring Program" be implemented separately from the projects.
- It is presumed that more that half of the Study Area has been subject to ground subsidence of 5-10mm/year. It is necessary to continue the observation of ground subsidences following a well established program.
- Lakes and ponds in the City area play a very important role in drainage and sewerage. They should be conserved for the future.
- Any works relevant to the West Lake should be preceded by a comprehensive environmental study on the Lake, which should be commenced as early as possible.
- It is recommended that unused lands adjacent to the pumping station and reservoir be reserved for the future expansion of the pumping stations and regulation reservoirs.
- Substantial improvement of rivers/lakes' water quality cannot be attained unless wastewater treatment systems are introduced. A feasibility study shall be conducted in order to accelerate the program's implementation.
- The role of the Urban Environment Company (URENCO), which is responsible for the collection and disposal of solid waste and excreta, is particularly important. The reinforcement of this institution, together with the provision of the necessary equipment and facilities, should be carried out under a separate aid program.

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4. America (North)

4.0 Introduction

This regional overview covers Canada and the United States of America. The approach to wastewater and stormwater management in this region is rooted on the European experience, but has developed in a different way to Europe and has its own distinctive characteristics. A significant contribution to the literature on this subject written in English has come from this region. What we understand to be modern practices has been associated with this region. The literature cited in this regional overview, particularly the manuals on technical design and practice, should therefore be referred to if readers wish to obtain further details on the subject.

In recent times as some of the wastewater and stormwater infrastructure has aged and needed replacement or considerable maintenance, some thought has been given to a shift of approach with regard to what can be considered environmentally sustainable way of managing wastewater and stormwater.

4.1 Wastewater characteristics (Topic a)

4.1.1 Cultural and technical practices

In general, human waste in North America is collected using water as the transport medium. High water use flush toilets, showers, appliances (e.g. clothes washing machines), dishwashers, and garburators result in relatively dilute wastewater in comparison to that generated in other parts of the world. To save water and wastewater treatment costs, as well as to save water in arid areas, there is now a growing trend towards the legislated use of water saving devices such as water meters and low flow toilets, shower heads and other fixtures, especially in new developments, which can reduce wastewater flows up to 30 percent.

Dry washing after urination and defecation using toilet paper (which is disposed of to the wastewater stream) is standard practice and is the cause of the relatively high amounts of cellulose fiber found in North American wastewater.

Most large cities, except those where the bulk of development occurred in the latter half of the twentieth century, have combined stormwater and wastewater sewers which affect wastewater collection and treatment. Since the use of the automobile is widespread, runoff from large paving areas often contributes to wastewater flow in urban areas. Trace contaminants from automobile exhaust, oil and fuel, and tires then become part of the wastewater stream.

Wastewater from large industries is generally treated on-site and then discharged into nearby water courses. Smaller industries, especially when located within or very near to a city boundary, may discharge into municipal sewers and contribute to municipal wastewater flows. In such cases, pre-treatment is generally required to adjust pH, reduce corrosiveness, reduce high solids content (to prevent obstruction of flow), reduce temperatures to below 40 degrees C, and prevent discharge of flammable materials that could create a fire and explosion hazard. Volatile organic compounds are also now largely regulated due to concern for air pollution, and the health of collection system and treatment plant workers. The release of volatile and toxic contaminants, and high strength conventional contaminants is often controlled through the use of Sewer Discharge Bylaws which restricts such discharges or applies heavy charges to discourage them.

4.11.2 Wastewater flows

Domestic wastewater

Domestic wastewater is generated by: dwellings, commercial facilities (e.g. stores, office buildings, airports, hotels, laundries, restaurants and shopping centres), institutions such as hospitals, prisons, rest homes and schools, and recreational facilities (e.g. pools, camps, resorts, golf clubs and parks). It is that part of the waste stream resulting from washing, bathing, culinary use, and human waste disposal.

There are generally two peaks in wastewater flow each day corresponding to sewage generated in the early morning as people get ready for the day, and early evening when they return home. A mid-day peak in wastewater flow may also occur. The number of peaks often depends on the size of the sewage collection system and the time it takes for sewage to reach the treatment facility. Lowest wastewater flows typically occur in the very late night to very early morning hours. Seasonal flow variations also occur due to inflow and infiltration of stormwater and groundwater into the sewer or due to changes in population (i.e. tourist and resort communities such as Banff, Alberta, and Aspen, Colorado, and in small communities serving colleges or universities).

The amount of domestic wastewater generated from residential dwellings ranges from 100 to 600 litres/capita/day with a typical average value of 260 litres/capita/day. Lower per capita volumes typically occur in areas with higher population densities, and areas with water use restrictions and controls. Areas with unreliable or limited water resources such as resorts with individual holding tank systems, also have characteristically low per capita sewage volumes. Higher per capita volumes are generated by lower density high cost housing with reliable water supplies, which tend to make heavy use of water using luxury appliances. Geography, such as water conservation in arid regions, does affect overall wastewater generation rates, but property value is a better indicator of expected per capita wastewater flow in individual cases.

Industrial wastewater

Large industries such as pulp mills, refineries, and power plants tend to treat (and often dispose of) their wastewater separately. This may be due to being situated in a remote location, or the prohibition of discharge to the municipal sewers due to the adverse impacts upon wastewater treatment systems of the associated high flows, high organic loads, high temperatures, acid or caustic solutions, or the presence of metals and other toxic contaminants. Smaller industries such as metal plating operations, or food processing industries that are located in urban areas often may discharge to municipal sewers. Flows from such sources may be highly variable, including batch operations and seasonal operations. Peak flows can be strongly affected in small communities with large industrial contributors. Many municipalities levy charges based on flow and contaminant loading from industrial users, which gives these industries economic incentives to investigate options for internal reuse and recycling of process water.

Infiltration

Sewers built in North America prior to 1970, using mortar or mastic joining materials, are particularly susceptible to infiltration from leaking joints, cracks and breaks in the collection system. Newer plastic and cast iron piping with elastomer gaskets have greatly reduced the amount of infiltration. Infiltration rates can thus range from 93 to 92,590 L/d/cm/km, with the higher rates usually in areas with high groundwater levels (Metcalf and Eddy Inc. 1991). An infiltration rate of 185 L/d/cm/km is considered to be reasonably acceptable for new systems.

Inflow

Inflow resulting from direct connection to storm drains, roof leaders, foundation and basement drains, and leaking manhole covers, is highly seasonal and geographical. In areas with combined sewer systems, all such flow is directed to the treatment plant, resulting in higher peak flows than expected from sanitary sewage flow alone. Wet to dry ratios in combined sewers (sewage to stormwater) range from 1:1 to 8:1, with median 4:1 (Metcalf and Eddy Inc. 1991). Although newer systems are separate, illegal connection of roof leaders, foundation and basement drains is common in small communities where building inspection may not be rigorous. A typical per capita allowance for infiltration and inflow in a separate sewer is about 150 L/capita/d .

A common design tool in use in North America is the Storm Water Management Model (SWMM), developed in 1971 and updated since by the U.S. Environmental Protection Agency (Athens, Georgia) [http://www.ccee.orst.edu/swmm]. This and other computer models are in general use, and require calibration with the system being modelled.

4.11.2 Wastewater biochemical characteristics

Concentration

Higher contaminant concentrations are associated with the low flow conditions described above, and lower contaminant concentrations are often associated with affluent areas and areas with combined sewers. Typical medium contaminant concentrations are shown in Table 1.

Industries which discharge a significant fraction of the total wastewater flow are often required to pre-treat before disposal to municipal sewers to bring their discharges down to typical sewage concentrations. Food processing industries can be a significant source of high seasonal solids, biochemical oxygen demand (BOD), nitrogen and phosphorus loading to a plant, resulting in seasonal concentration changes, especially in agricultural areas with large numbers of food processing industries.

In combined sewer systems, the "first flush" effect is often observed during a storm event in an area with relatively flat sewers following a dry period. The scouring of solids and associated contaminants deposited in the pipes results in a high solids and contaminant load to the treatment plant soon after the beginning of the storm. In such cases, the solids concentration may increase slightly as the flows increase rather than being diluted by the stormwater as would be expected. The effect typically lasts for only a few hours, and is followed by the expected dilution if the storm persists. The parameters most affected are solids concentration and biochemical oxygen demand (BOD_5), but toxic inorganic and organic contaminants adsorbed to the solids will also exhibit a concentration peak. Strategies to control the impact of combined sewer overflows often involve treating this “first flush” by capturing the initial flow in a reservoir, and treating the remainder through a vortex style stormwater solids separator. Once the storm is over, the stored liquid is pumped back into the sewer to be treated at the treatment plant.

Combined sewer systems produce higher total solids per capita loading than separate sewers because of a higher amount of inorganic solids in the waste stream. Stormwater runoff can be as high as 100 mg/L suspended solids. Typically, inorganic solids comprise 25 percent of total suspended solids entering a treatment plant in separate sewers.

The organic fraction of total suspended solids is affected by the high cellulose content from toilet paper. The organic fraction in sludge from wastewater treatment plants is thus typically less than 50 percent readily digestible. The use of garburators in a community can increase the per capita solids load by 30 percent or more.

Septage discharged into the wastewater plant can be very high in solids, 2000 to 100,000 mg/L including gravel and cobbles. The organic material is partially digested, thus septage solids tend to be higher in the inorganic fraction than the rest of the waste stream.

Table 4.1: Typical Composition of Untreated Domestic Wastewater – medium strength

Contaminants	Unit	Concentration Medium
Solids, total (TS)	mg/L	720
Dissolved, total (TDS)	mg/L	500
Fixed	mg/L	300
Volatile	mg/L	200
Suspended solids (SS)	mg/L	220
Fixed	mg/L	55
Volatile	mg/L	165
Settleable solids	mL/L	10
Biochemical oxygen demand,:		
5 day, 20°C ($BOD_{5,}$ 20°C)	mg/L	220
Total organic carbon (TOC)	mg/L	160
Chemical oxygen demand (COD)	mg/L	500
Nitrogen (total as N)	mg/L	40
Organic	mg/L	15
Free ammonia	mg/L	25
Nitrites	mg/L	0
Phosphorus (total as P)	mg/L	8
Organic	mg/L	3
Inorganic	mg/L	5
Chlorides[a]	mg/L	50
Sulfate[a]	mg/L	30
Alkalinity (as $CaCO_3$)	mg/L	100
Grease	mg/L	100
Total coliform	CFU/l00 mL	10^{7}-10^{8}
Volatile organic compounds (VOC_s)	µg/L	100-400

[a]Values should be increased by amount present in domestic water supply.

Source: Metcalfe & Eddy, Inc. (Tchobanoglous, George, Burton, Frank) Wastewater Engineering: Treatment, Disposal & Reuse. Third Edition. McGraw Hill, 1991.

BOD_5

Biochemical oxygen demand domestic loads can be increased by 30 percent if garburators are in use in a community. Stormwater runoff only accounts for about 5 percent of total BOD_5 load in combined sewer systems. Septage pumpouts have very high BOD_5 concentrations, typically ranging from 2,000 to 50,000 mg/L. Restaurants in resort areas can also be major contributors to plant BOD_5 loads, and oil and grease from such operations can be a nuisance in the treatment plant downstream.

Nitrogen and phosphorus

Besides human and culinary waste, other sources of nitrogen and phosphorus are agricultural runoff into storm sewers, food processing industries and fertilizer industries. These nutrients are a major problem in many areas of North America, particularly when discharging to inland water bodies. Phosphorus in laundry detergents was banned in some areas of the U.S. and Canada, and as a consequence few detergents sold in North America now contain phosphates. Some resort lakes, for example Okanagan Lake in British Columbia, surrounded by increasing development began developing problems with nuisance weed and algal growth. Stringent local requirements to limit nitrogen and phosphorus levels in wastewater effluent were implemented to control the growth and maintain water quality, requiring tertiary level wastewater treatment.

pH and Alkalinity

pH and Alkalinity are mainly a function of local geography and whether the local water source is groundwater or surface water, with surface water tending to be less mineralized. Although acid rain over much of the continent results in many surface drinking water sources having pH as low as 5 or less, wastewater tends to be roughly neutral or slightly basic pH. Industrial wastewater can have extreme acid or basic pH. In the event nitrification is required to eliminate effluent ammonia toxicity to fish, low alkalinity wastewater can result in low pH levels. Consequently, it is often advisable to denitrify to recover some of the alkalinity and energy used for nitrification. During denitrification, bacteria use nitrate and nitrite as an electron source, reducing the overall energy required for aeration.

Temperature

Temperature of wastewater in North America varies widely, with larger seasonal variations in Canada and the northern United States. Some low technology options which would otherwise be appropriate, such as wetlands, cannot be used in some northern areas because of freezing and thus only seasonal treatment. Biological nitrogen removal is also affected by low wastewater temperatures, although nitrification has been observed at plants with liquid temperatures as low as 4 ^oC. Higher temperatures in the south, which can be as high as 30 – 35 ^oC, result in year-round odour control issues.

Chlorides and sulphates

Wastewater chloride concentration may be high in communities with high groundwater tables, and saltwater intrusion into groundwater or near shore sewage pumping stations. Chlorides may also be high in communities with hard water, where individual water softeners are in common use. The presence of chlorides, in sufficiently high concentrations, can interfere with sewage treatment.

Sulphates formed in long, low slope sewers in warm climates have proven to be a corrosion problem in older plants with concrete tanks, and in older sewers. They can also contribute to severe odour problems. This condition is commonly controlled by injecting ferric chloride upstream of the odour release point to control hydrogen sulphide formation.

Toxic inorganics and priority pollutants

The EPA has identified a number of priority pollutants based on known or suspected carcinogenicity, mutagenicity, teratogenicity or high acute toxicity. Examples are heavy metals, halogenated organic compounds, and pesticides. The main controllable sources of such contaminants are industrial users of the sewer system. The implementation of Sewer Discharge Bylaws that levy charges for contaminant loading is used to reduce this loading, as the bylaw makes it more cost effective for industries to initiate source control measures and treat the wastewater before discharge to sewer.

Contaminant loading from residential and commercial sources is more difficult to control and regulate. When combined with low mineralization, low pH water tends to leach metals from the water distribution system, resulting in relatively high copper and iron loads at wastewater treatment plants. As well, there are still some homeowners and small industries who find it easier to dispose of hazardous wastes such as cleaning solutions to the sewer rather than pay for proper disposal or take the hazardous waste to a collection site. Public information and education programs have been used to reduce contaminants from residential and commercial sources by educating people as to the environmental effects of discharging materials such as latex paints and pesticides to the sewer.

Stormwater road runoff is another source of trace metals and petroleum products. Public education programs have been effectively used to reduce the discharge of toxic contaminants and hydrocarbons to storm drains. One of the more effective programs is a community initiative to paint fish symbols next to catchbasins to remind people that materials discharged to the storm drain affect fish.

Many contaminants, especially ionic metals, tend to become adsorbed to fine solid particles in the sewage and to bacteria in the waste treatment process, and become part of the waste sludge stream. In some cases, the contaminant concentrations in the sludge can be sufficiently high enough that they limit disposal options for the biosolids generated by the wastewater treatment process, and may even inhibit sludge digestion.

4.2 Collection and transfer (Topic b)

Sewage is generally conveyed to a treatment facility by gravity piping, and/or pressure force mains. The exceptions are small on-site systems such as pit privies, composting toilets and incinerating toilets in which there is no need for sewage conveyance.

4..2.1 Wastewater

Transport from on-site systems

On-site treatment systems typically serve single dwellings, or small clusters of dwellings. They are used when central collections systems are not available or are not economically practical due to disperse population, difficult construction (shallow rock), or other practical constraints. On-site treatment systems typically dispose of treated effluent directly into the ground, and rarely into surface waters such as creeks, rivers, and lakes, although marine discharges may be permitted in certain jurisdictions

In Canada, 20-25% of the population lives in rural surroundings, much of which is unlikely to be provided with municipal piped services. In the United States approximately 35 percent (about 87 million) of the population is served by non-centralized treatment and disposal systems, and this percentage is expected to increase over the next ten years.

Waste sludge generated by these systems may be in the form of septage from septic tanks, waste activated sludge from small activated sludge plants, or chemical and biological sludge from small industrial pre-treatment plants. The sludge is usually taken from the site by vacuum trucks, and transported to a nearby central facility for co-treatment and/or disposal. The central facility may be a wastewater treatment plant with a special septage receiving station, or it may be a composting or lime stabilization operation. Landfilling, while prohibited in many locations, is still practiced in various parts of North America.

On-site systems can also be incorporated into central collection systems such as the septic tank effluent pumping (STEP) process, small diameter variable slope piping, or vacuum piping systems.

Individual household septic tanks provide pre-treatment (grease, oil, and solids removal) in STEP systems. Septic tank effluent is then pumped into small diameter (25-50 mm) plastic pipes using a small (1-2 horse power) grinder pump, and the effluent is transported to a common secondary treatment facility through a low pressure or gravity-flow collector sewer. A typical application location would be housing located along a shoreline, or areas where conventional deep trench sewer construction is economically impractical due to the presence of rock near the surface.

Advantages of the STEP system include the use of low cost small diameter pipes (from 2 inches (50mm) to 6 inches (150mm)); pipe layout which is independent of topography; reduced excavation, infiltration, and manholes compared to gravity sewers; less power requirement than vacuum systems, and typically lower construction costs than other alternatives. Disadvantages include the need for effluent pumps or grinder pumps at each residence; electrical power is required; air release valves are needed; flushing connections are required for periodic pumping of septic tank; and power outages disturb service.

Small diameter variable slope systems are also used with septic tanks, but the tanks are fitted with a positive method for solids removal such as an effluent filter vault, internal deflection baffles, and inclined clarifier tubes. A net positive slope from inlet to outlet is required, but pipe is laid at a constant depth regardless of grade. The resulting flow regime includes surges, delays, transitions from full to partial pipe, and continually full sections of pipe. Air release valves are required. Cleanout ports are installed instead of manholes, and piping is cleaned by pigging. This technology was developed by Rural Housing Research Unit of USDA-ARS, Tuskegee Institute, and Farmer's Home Administration.

Vacuum collection systems combine gravity flow from the wastewater source to a holding tank upstream of a vacuum ejector valve, which seals the vacuum from the main pipe, and opens automatically on tank level allowing a plug of liquid to enter the main. A central vacuum pump station maintains the vacuum main at approximately 400 mm Hg. This type of system is not generally cost effective compared to small diameter variable flow or STEP systems. This type of system is typically used in areas with limited water sources, small low-lying areas such as marinas, or ski resort facilities on the tops of mountains (e.g. Whistler Mountain, B.C. Canada).

Advantages of vacuum systems include: electrical power is not needed at each residence; reduced excavation compared to gravity sewer systems; grade and depth of trenching is not critical; exfiltration is virtually impossible; and manholes are not needed. The disadvantages include: electrical power is required at central vacuum station; vacuum valves have a shorter life than pumps; the system has higher energy consumption than other alternatives; there can be major odor problems at the central vacuum station; and vacuum loss (system break) requires immediate repair.

Gravity systems

Gravity collection and transport systems for wastewater are the most common in North America. They are usually the most economic system if the topography is favourable. Their performance is well-established and documented, and their design, construction and operation are well understood. The systems include a combination of gravity sewers, pump stations and forcemains.

Piping for new gravity systems is plastic, with PVC being the most likely choice. Bell and spigot joints with elastomer gaskets are usually used for diameters less than 200 mm. In larger sizes, common choices include PVC, ribbed polyethylene piping, and reinforced concrete piping, all with elastomer gaskets. The choice is usually dictated by both economics and design conditions. A consideration however is sulphate corrosion of reinforced concrete piping - although sulphate resistant cements are available.

Where a collection area is lower than the overall system, wastewater must be pumped. Stations handling smaller flows generally use submersible pumps installed in a wet well, while larger stations will often use separate pumps in a dry well for ease of maintenance. Underground forcemains are usually made of plastic, but piping in dry and wet wells is usually made of coated steel for durability. Odour control for pump stations and forcemain outlets can be an issue, and biofilters and carbon filters have been used successfully for odour control.

Infiltration minimization for wastewater management cost control is a concern in many communities, especially those with older sewers. In-situ lining of old piping often is an economic solution, and is often referred to as no-dig or no-trench sewers. There are a number of methods in which smooth liners are installed in pre-existing old sewer pipe to increase the capacity of the pipe and reduce or eliminate the infiltration of groundwater into the pipe.

4.11.2 Stormwater

The high percentage of paved land in urban North America has increased the amount of stormwater runoff from streets and parking areas, and reduced retention time before release to surface water resulting in sharper and higher flow peaks. Paved areas are sloped to catchbasins, which collect refuse before stormwater enters piping. Piping materials are generally the same as for sanitary sewers, with the exception that sulphate resistance is typically not an issue. The pipe is usually sized based on a design year storm event, with the specific recurrence period specified by local or regional codes.

Small areas such as parking lots, or industrial sites such as mill yards with specially contaminated runoff, may treat the stormwater runoff prior to discharge to a central stormwater or combined sewer system. Green space around individual homes, in parks, and in agricultural areas within urban catchments is often used to provide a passive form of stormwater treatment and transportation/retention, linked by ditches and culverts.

Combined sewer systems (storm and sanitary combined) often exist in older large urban communities; a result of common practice in the early 20th century. Over 45 percent of communities in the US with populations greater than 100,000 have combined sewers (Metcalf and Eddy Inc. 1991). Many communities are separating them as they replace the older infrastructure. In new developments, stormwater piping is now separate from sanitary sewage piping.

Stormwater control

Overland flow, or runoff, is sometimes directed into control structures to flatten peak flows, especially in combined systems which discharge to a treatment plant. Swales (flat grassed ditches) are used to direct flow around structures. Ponds, which may be dry grassy areas and part of parkland in the dry season, are allowed to fill and drain naturally. Peak flows may also be diverted into reservoirs, which are drained later when stormwater flows abate.

Technologies for stormwater diversion and flow control range from simple side weirs, to automatic gates which respond to water level, tipping gate regulators whose motion is controlled by water level upstream and downstream of the gate, and Hydro-Brake regulators. The latter, a patented device, causes centrifugal motion in the entering liquid, which decreases the amount of water passing through the outlet and maximizes flow storage in the upstream sewer.

4.3Treatment (Topic c)

4.3.1 Small scale and community scale technologies

In the following discussion, small and community scale is defined as from 1 to 5000 Population Equivalents.

Stormwater

Swales, wide shallow grassy ditches, are used to direct stormwater flow around a surface structure, and provide some flow attenuation, filtering, and evapotranspiration due to the grass growth, as well as some minimal storage. Ponds are used to contain stormwater flow, hold flows until pollutants are biologically broken down or adsorbed onto particulate matter, and often allow water to infiltrate into groundwater gradually through the pond bottom. Sedimentation and filtration ponds may also be lined to facilitate removal of accumulated sediments, usually every two to four years. Ponds and swales are also effective in removing sediments from storm discharges, but are land intensive.

Ponds are also used to treat runoff from parking lots. These systems may also include upstream filtration provided by grass plots underlain by sand and gravel filters with an underdrain system feeding the holding ponds.

Natural, enhanced and artificial (constructed) wetlands are also used to treat stormwater runoff before discharge to the environment. Application is similar to that discussed under wastewater treatment below. Water may be diverted through a natural wetland system to take advantage of adsorption phenomena in the removal of sediments, and inorganic contaminants (metals). These natural systems may be enhanced to optimize the level of treatment and water attenuation.

Stormwater treatment can also be achieved in systems consisting of rock berms and alternating strips of native grasses and stiff grass hedges constructed on slopes. The rock berms are intended to catch coarse sediment and floatables, and convert piped flow to sheet flow down the slope. Native grasses provide screening, vegetative filtering and infiltration. Coarse hedge forming grasses provide flow attenuation to prevent flattening of filter grasses. Mowing and trimming of the site removes nutrients accumulated in the vegetation. This type of system has been applied in Austin Texas as part of a new subdivision, and requires less space than ponds.

Where space is at a premium, or where the groundwater table is high, radial flow filter cartridges installed in manhole structures have been used. One manufactured type, the Stormfilter^{TM}, has been installed in more than 130 sites in the U.S., including shopping centers, restaurants, highway runoff, hospitals, and single retail outlets [http://www.stormwatermgt.com/products.html]. Runoff from impervious surfaces such as roads and parking lots are treated by humic filter media composed of pelleted composted deciduous leaves. Up to 90% removal of solids, 85% removal of oils and greases and over 80% removal of heavy metals are claimed for such systems.

Small versions of vortex grit and floatables removal systems, such as the Downstream Defender (Storm King) or Vortex Separator (US EPA Design Criteria), have been used as a pretreatment stage for discharges prior to discharge to a gravel leachfield [http://www.hil-tech.com/dwnstrm.html]. Generally, there has been little detailed testing of the benefits derived from these large scale vortex flow devices. Research data indicates these vortex style systems typically remove only the coarsest fraction of the suspended solids, whereas toxic contaminants are more typically associated with the finer particulate fraction.

Catchbasin inserts have also been used to provide runoff treatment from debris control using mesh bags and screens, to oil and heavy metals removal by filter absorption. Rigorous catchbasin cleaning schedules become very important to maintain the drainage capability of the system. Simple oil traps such as submerged outlets on catchbasins are also used. The use of polypropylene sponges are recently being commercially promoted for use in catchbasins to absorb oil contained in the runoff. The hydrophobic oil containing sponges are periodically collected and processed.

Best Management Practices (BMPs) are encouraged on industrial and construction sites to prevent stormwater contamination at site. They include covering piled materials, roofing equipment storage and maintenance areas, covering drum storage systems, routine cleaning of paved surfaces, use of sedimentation basins and straw filters to trap runoff associated sediments migrating from the construction site, and regular inspections of potential problem areas. Drain blockers can be used in maintenance and equipment wash areas. On construction sites, erosion and subsequent large solids loads to the stormwater collection system can be controlled using methods such as Ditch Dams^{TM}, a proprietary product composed of wire mesh and geotextile moulds which are filled with dirt and ready-mix cement on site [http://www.gullywasher.com/ditchdam.html].

Wastewater

Individual toilet systems

Pit toilets are generally used on remote, low density private and public recreational properties. Chemical toilets, whose contents are periodically pumped out by vacuum truck and transported to a central treatment facility, are widely used under temporary circumstances such as construction sites. Originally mainly used for remote recreational property, composting toilets (eg. Dowmus Composting Toilet illustrated in Figure 4.1) are now often used where a conventional septic system has resulted in water pollution, as well as for parks, beaches, highways, military installations, and golf courses [http://www.dowmus.com/home.html]. Imported from Sweden, North American modifications have included computer control functions, including positive mixing of the contents of the tank (Toilet Tronic, BC) and foam flush with an insulated composting tank for arctic regions (AlasCan Composting Toilet) [http://www.alascanofmn/index.html]. Incinerating toilet technology is used most often in mobile offices, boats, cottages cranes**.**

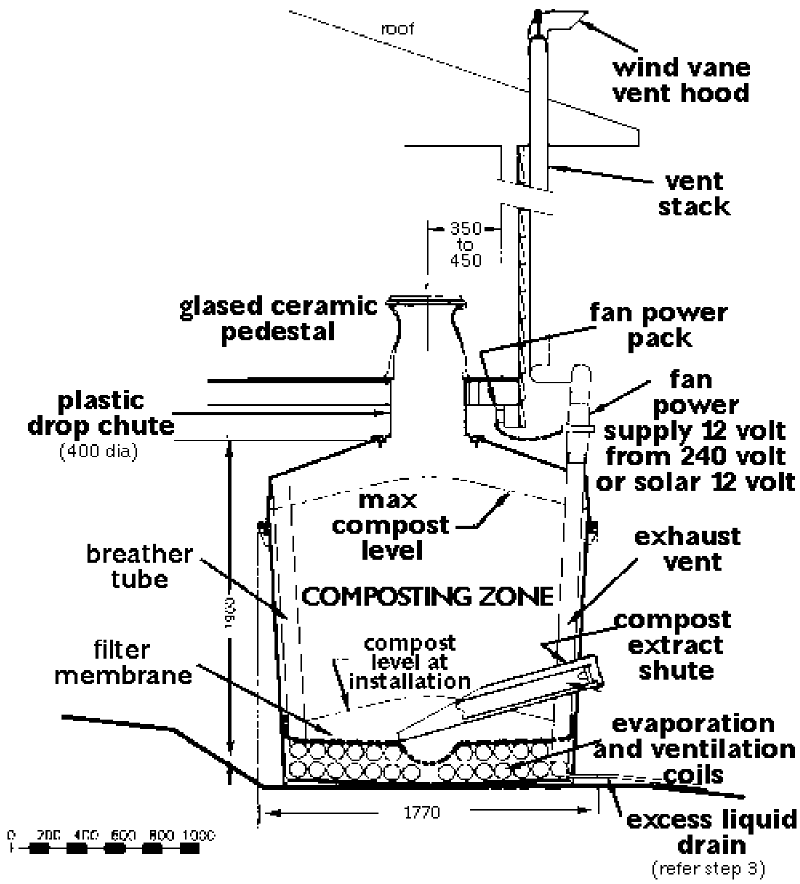

Figure 4.1: Diagram of the Dowmus Composting Toilet

Individual homes

Wastewater technology for individual homes ranges from primary treatment in a septic tank, separation followed by ground disposal, to small package mechanical wastewater treatment plants. In some environmentally sensitive areas, especially those depending on tourist revenues such as the Florida Keys, nutrient removal is an important issue.

There is a performance standard for individual household wastewater treatment systems, referred to as the ANSI/NSF Standard 40. This standard was developed by the National Sanitation Foundation (NSF International) in Ann Arbor Michigan (a not-for-profit organization) on behalf of the American National Standards Institute (ANSI) to verify manufacturer's claims regarding performance. It is a voluntary certification testing program, which many Health agencies throughout Canada and the US have come to rely on. Testing under this standard is carried out in both Canada and the US at three locations: 1) Chelsea, Michigan; 2) North Saanich, British Columbia; and 3) Baton Rouge, Louisiana. Testing is carried out over a 26 week period, and involves monitoring treatment performance under standard loading and stress testing conditions.

a. Septic systems

Approximately one-quarter of all homes in North America are served by septic tank systems. Most tanks are constructed of concrete or fiberglass. Two compartments tanks are favoured due to more positive prevention of solids carryover to a drainfield. Tanks used as pretreatment before small diameter piping collection are fitted with filter vaults.

b. Biofiltration

There are many different kinds of biofilters which mimic the action of wastewater degradation in unsaturated soil, and are generally used where local soil conditions or development density preclude disposal in conventional septic tile fields. In addition to low BOD_5 and TSS in biofilter effluents, fecal coliform counts are often significantly reduced, although this is not typically relied upon for final disposal due to the possibility of filter short-circuiting. The filters described below are usually used for single family dwellings but have also been applied for small home clusters. Effluent is generally nitrified, with approximately 50 percent removal of total nitrogen, but with the exception of peat filters, biofilters are not generally effective for phosphorus removal.

Intermittent sand filters are tending to be designed at lower loading rates and using finer media, to improve fecal coliform removal. Required piping, filter cloth, pumping equipment and controls can be purchased in a kit form for construction and installation by knowledgeable installers.

The Waterloo Biofilter™ (Figure 4.2), developed at the University of Waterloo, uses an absorbent plastic foam media and positive fan ventilation to allow loading at ten times the rate of an intermittent sand filter [http://oceta.on.ca/profiles/wbsi/bi.filter.html]. Nitrogen removal can be effected using recirculation, or by passing the effluent through a free draining sawdust box. Phosphorus removal is effected by passing the effluent through a ferric iron mineral filter. The Waterloo Biofilter has been installed in several locations in Ontario, one in Massachusetts, and one in Nova Scotia.

Upflow filter systems intermittently dose septic tank effluent below a bed of media, allowing solids to settle and decompose below the bed, while liquids rise through the media and treated effluent overflows over the top. The Glendon Biofilter, developed in Washington State operates in this fashion and the distributors claim it achieves a 10/10 (BOD/TSS) effluent. This system is typically designed for single home applications.

Peat filters treat septic tank effluent by gravity distribution by conventional leachfield piping over a buried peat filter. Sphagnum type peat is used. At least thirteen peat filter systems are in operation in Ontario, ranging from single family systems to schools. The filters have proven effective in reducing phosphorus, and BOD_5 at appropriate loading levels. Nitrogen reduction is on the order of 40 to 60 percent.

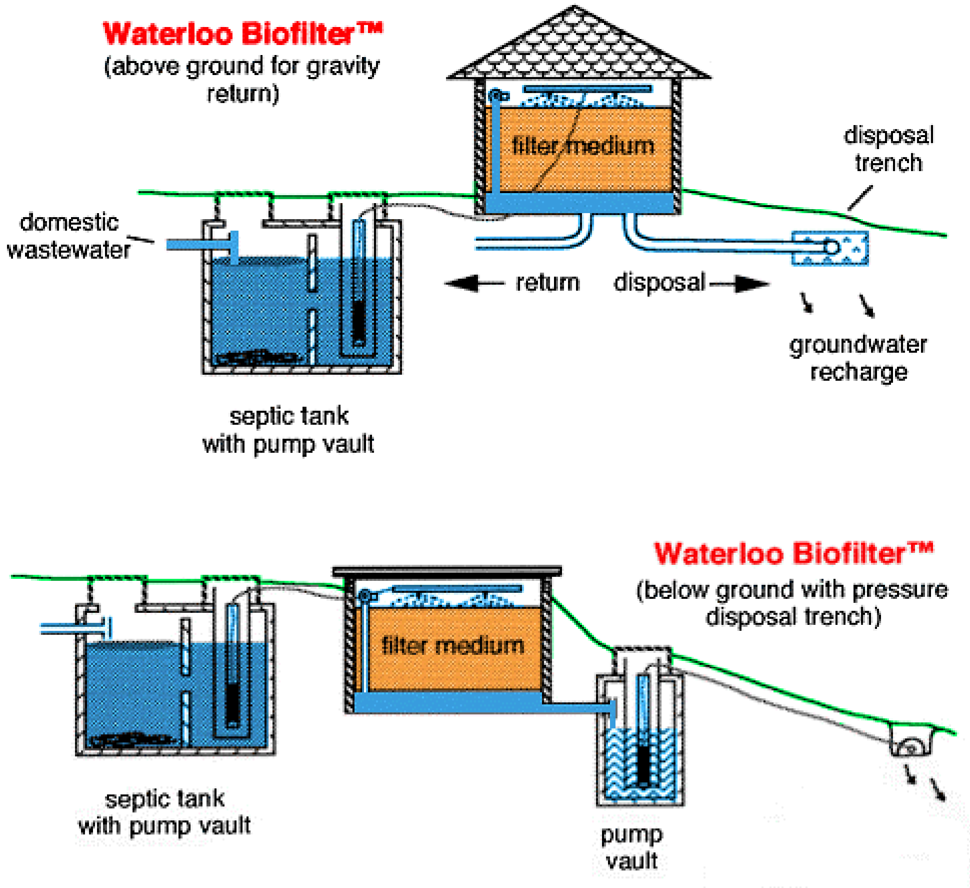

Figure 4.2: Waterloo Biofilter System

c. Mechanical package plants

Single family dwellings have historically been supplied with either simple activated sludge plants or rotating biological contactors in integrated single tank systems. Newer technology combines both suspended and attached growth systems (moving bed biofilm reactors) with either fixed or floating media submerged in a suspended biomass. The combined systems are theoretically more resilient to shock flows and loads. These systems effect some nutrient removal, mostly in terms of nitrogen removal.

Solids separation is usually by clarifier, generally oversized by large system design standards to allow for wide flow variations, with no positive scum or sludge removal. Solids buildup is pumped out by vacuum truck at regular intervals and hauled to central treatment facilities.

Biofilters have also been used with some success to improve effluent solids quality. Other types of solids separation systems, (such as ultra-filtration membranes) are available, but are generally not cost effective in single home situations; they are discussed in the following section.

Where single home systems discharge to a surface water body, disinfection is used. Options include chlorination/dechlorination using solid puck systems, single lamp ultraviolet disinfection systems, and ozonation. Ozonation is available as part of a package treatment plant developed by Hydroxyl Systems Inc, based in British Columbia, Canada [http://www.hydroxyl.com].

Small communities

Small communities use a variety of technologies from simple pond systems to more complex mechanical treatment plants.

a. Pond systems

Pond systems are popular in rural areas with available land area but low operational expertise. In 1984, there were 5298 stabilization ponds in use in the United States, with a further 2783 planned (Water Environment Federation; see 4.10 Sources of information).

In Canada, almost 9% of the population surveyed in 1996 with central sewage treatment was served by stabilization ponds. The actual number may be higher as communities with less than 1,000 persons were not surveyed ([http://www.ec.gc.ca/water/en/manage/vse/e-datab.htm] Environment Canada). Shallow aerobic ponds are used mainly in the southern part of the United States. Anaerobic ponds are generally used for strong industrial wastes rather than for municipal wastewater. Facultative ponds are the most common, and are in use in all climatic regions. Algae growth in these types of ponds can contribute to seasonal high solids concentrations in the effluent. Where wastewater temperature are sufficiently high enough during the summer, near complete nitrogen removal can be achieved (i.e. up to 95%).

In 1984, there were 1368 aerated lagoons in use, with a further 1494 planned (WEF). Aerated lagoons are often designed as several smaller ponds in series. A few more recent systems have provided high mixing in the first cell, followed by lower levels of mixing in subsequent cells to help prevent algae production.

Integrated lagoon systems combine facultative primary cells with fermentation pits acting as upflow anaerobic digesters followed by a shallow aerobic lagoon, with recycle back to the facultative lagoon. A system in St. Helena, California, has been operating for 27 years.

Lagoon discharges may be controlled to protect the receiving environment, discharging only when receiving stream conditions are satisfactory. Some lagoons, located where evaporation exceeds precipitation, can be designed as zero discharge.

Lagoon designs are tending towards more positive pond lining, including geosynthetic clays and geomembranes. Odour from anaerobic ponds is controlled using floating covers with gas collection.

Plant harvesting, a form of smaller polishing pond treatment practiced in warmer climates (air temperatures above 7 deg. C) involves growth and harvesting of floating aquatic plants such as water hyacinths and duckweed. Water hyacinth systems are in place in Headlands, Alabama, and San Benito, Texas. They have been used for nitrogen removal in Florida. Phosphorus removal is not practiced.

b. Overland flow

Overland flow systems aerobically treat wastewater, providing secondary treatment and nitrogen removal. Pretreatment includes at least screening. Recent practice adds a short detention time aerobic lagoon upstream for solids removal and addition of dissolved oxygen. Public access to the application site is not allowed. The technology is mainly used in the southeastern and southwestern U.S. In cold weather climates, winter storage is required as treatment efficiency, especially nitrogen removal, is adversely affected by cold temperatures.

c. Wetland systems

Wetland systems are used to treat primary and secondary effluent, especially when discharging to a sensitive environment locations. Typical wetland plants include cattails, reeds, rushes, bulrushes and sedges. The plants are not usually harvested, though in some systems they may be periodically burned off to maintain system hydraulics. Operation is possible in cold climates, although storage may be required and the effect of freezing must be allowed for. Constructed free water surface (FWS) wetlands can have a secondary purpose as wildlife habitat, although mosquito control is an issue. FWS wetlands are more common in the U.S. than subsurface flow wetlands. Subsurface flow wetlands have been used for residential sewage treatment in Canada since the early 1990s, but only since about 1995 in the US.

Natural wetland systems can and have been adapted for wastewater treatment but are more likely to be a final disposal point, since adaptation of the natural wetland may harm the local ecosystem.

d. Tank systems

Communities may have a single septic tank system followed by a large leachfield (i.e.: Taylorsville, California). Large septic tanks are used upstream of mechanical treatment, such as rotating biological contactors in community sized installations. Imhoff tanks have been used for small communities in the past (U.S. EPA survey in 1988, flows of about 0.95 MLD, 415 facilities) however they are now prohibited in some states. Operational problems include odour problems and production of odorous foam and sludge.

e. Mechanical treatment plants

All of the technologies in use for single family dwellings are available in larger scale for use in small communities. The usual refinements include positive sludge and scum removal from clarifiers, and sludge holding tanks which, if aerated, also act as mesophilic aerobic digesters. Installation of rotating fine screens upstream of the mechanical treatment plant decreases buildup of floatable material.

Multiple tank systems with recycle, such as the Biogreen system imported from Japan, are claimed to be capable of up to 50 percent nitrogen removal.

In this size range, recirculating intermittent sand filters are used rather than the single pass systems used for individual homes.

Sequencing batch reactors (SBR) are economically competitive over 150 m^3/d, and have been used with success in many locations throughout the US and Canada. SBR's have computer control allowing easy manipulation of react, settle and decant times to allow for changing inlet conditions.

Remote monitoring of community-scale plants by telephone and by satellite is available and becoming more common, allowing a central monitoring station by a manufacturer to contact a local operator and assist with maintenance. Remote monitoring of single family dwelling systems is possible, but is not generally done due to the high cost of equipment and telephone lines.

Besides secondary gravity settling, other solids separation technologies used at this scale include dissolved air floatation, and membrane filtration.

Advances in dissolved air floatation include improved air entrainment using venturi devices which enable equipment manufacturers to use shallower tanks than conventionally possible. These systems, such as the Hydroxyl Systems Inc. Positive Floatation Mechanism (PFM), are also finding application as primary and secondary solids “clarifiers”, and research suggests that the highly aerobic sludge cap at the surface results in accelerated solids destruction and denser sludge in such applications (Figure 4.3).

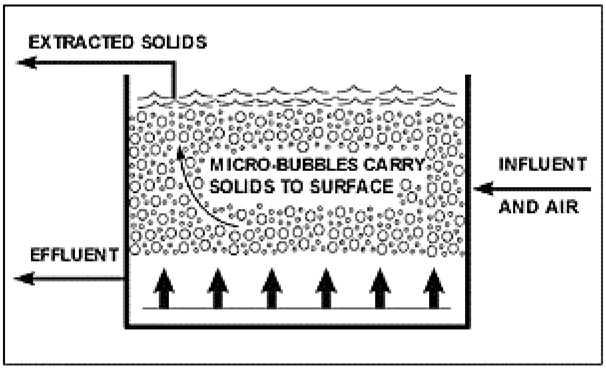

Figure 4.3: Hydroxyl Systems Inc. Positive Floatation Mechanism (PFM)

Membrane filtration technology operates either downstream of high solids concentration activated sludge secondary treatment, or within the aerated bioreactor of such systems. Effluent may be either forced by pressure through wound tubular membranes, or drawn by light suction through the membranes using vacuum pumps. Nominal pore sizes are typically small enough to filter out bacteria, but cracks or breaks in the membrane may permit bacteria to cross over the membrane barrier. An example of a commercially available membrane used in a wastewater treatment membrane-bioreactor process is the Zenon Environmental Inc. ZeeWeed® membrane system illustrated in Figure 4.4 [http://www.zenonenv.com/zeeweed.html]. Computer controlled pressure variations and/or periodic backwashing help to keep the membranes clean. Nitrification is generally good due to the very long sludge ages achieved in membrane systems, but denitrification and overall nitrogen removal depends on the system design and presence of anoxic/anaerobic reactors within the process. Phosphorus removal I membrane systems typically requires chemical addition.

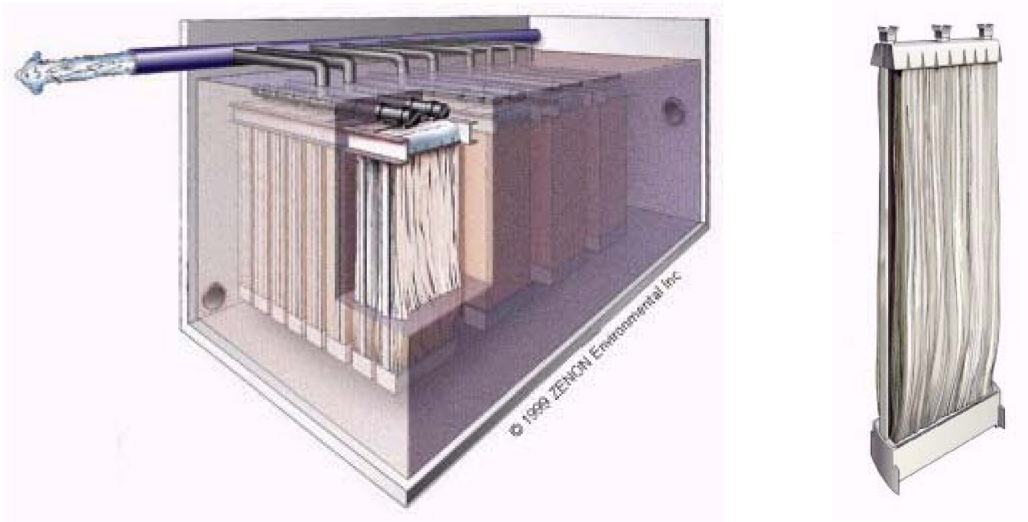

Figure 4.4: Zenon Environmental Inc. Membrane Bioreactor System And Zeeweed® Membrane

Physical/chemical treatment using chemical flocculation was practiced in the past to treat wastewater with widely varying flows and loads, especially high loadings. Greater understanding of biological wastewater treatment, complex operational and maintenance requirements, and more stringent requirements for chemical sludge disposal has resulted in fewer installations of this type. However, there are still instances where biological wastewater treatment may not be practical - for example, where a mobile unit requires instant treatment without a startup time allowance. Electro-flocculation has been applied to industrial processes in the past, and is now being developed by companies in Canada, and the US, for use with wastewater treatment.

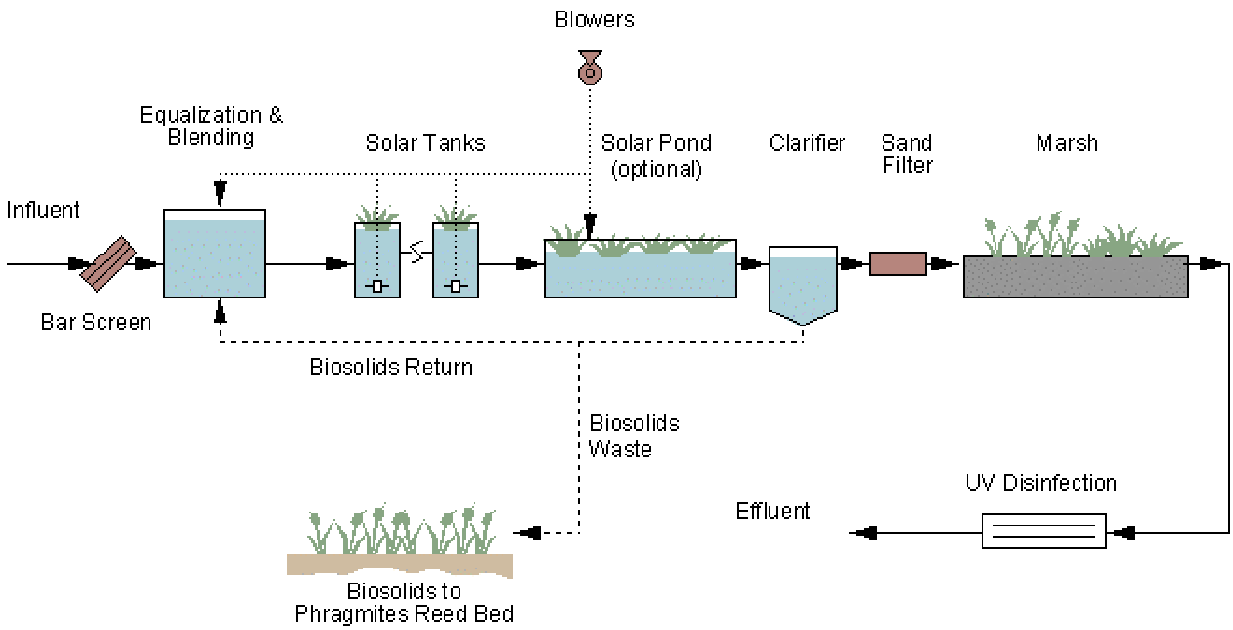

Figure 4.5: Solar Aquatics Treatment System

Source: http://www.computan.on.ca/~fleet1/wastewater/solar.htm

One technology (developed in Massachusetts by Solar Aquatics, and illustrated in Figure 4.5) combines activated sludge and constructed wetlands in a package plant located inside a greenhouse.

f. Odour control

Especially for small community installations located near homes, odour control can be an issue. Technologies used include activated carbon filtration, chemical scrubbing and biofiltration. Biofilters for odour control are above ground piles of composting material (often woodchips) with spray wetting systems and underdrains to collect filtrate. Modular biofilter systems consisting of stackable trays have also been developed.

g. Grease traps

Simple grease trap tanks have been generally used on wastewater discharges from restaurants, laundromats and service stations to prevent plugging of the downstream treatment system. A change to use of low temperature soluble vegetable oils rather than animal fat has resulted in these traps being less effective. Solutions have included the NIBBLER, a combination of attached and suspended growth secondary treatment technology developed in Oregon, and enzyme additives [Nothwest Cascade-Struth, Puyallup, Washington WA 98373; ph: 800 4442371]. Although the technical basis for such additives is questionable, some users of additives have reported good results.

4.3.2 Large scale technologies

Stormwater

Modeling

In large scale stormwater collection systems, computerized flow models are often used to evaluate control measures. Models can be proprietary software, calibrated to a particular system, or developed in house either fully or from combinations of proprietary software. Use of the models has demonstrated in some locations that less costly control measures can be used to satisfy local regulatory authorities effluent discharge requirements, particularly from combined sewer overflows.

Flow control

Large cisterns have been constructed in some major cities to hold stormwater for release after a storm event has passed, thus reducing the size of the peak flow on the system. They are often located under parks, for ease of construction, to avoid other underground utilities. For example, the Cole Park detention vault in Dallas Texas, can accept and discharge a 50 year rainstorm within 24 hours. It consists of thirteen parallel tunnels. The upper 33 percent of the vault drains by gravity, and the remainder is removed by a submersible pump station. The system protects a highway crossing whose 4 m diameter culvert could not handle the peak runoff rate.

Vortex valves are used in some locations to restrict flow to the sewer at higher flow rates, thus maximizing upstream storage in the system. The vortex induced by high flows causes an air core in the flow which reduces pipe discharge from a manhole.

Treatment

Simple floatables control using stainless steel underflow baffles installed in existing combined sewer bypass manholes will be installed in the Massachusetts Water Resources

Authorities sewer system. Laboratory testing and computer modelling indicates the system should work well. Each baffle was designed separately for the flow conditions and dimensions of the existing structures.

Vortex separation is used to remove coarse settleable solids and floatable material, as well as grease, from stormwater flows and combined sewer overflows. The units are available in sizes ranging from manhole inserts to separate underground concrete vaults for higher flows.

Figure 4.6 illustrates one such system manufactured by Vortechnics Inc [http://www.vortechnics.com/]. Flow is introduced tangentially to the chamber, grit impinges on the walls and falls to the bottom while clarified flow exits from the top of the chamber. Oil and floating solids are trapped behind underflow baffles, or by submergence of the outlet pipe at higher flows. The systems are designed to prevent re-suspension and release of solids at high flows.

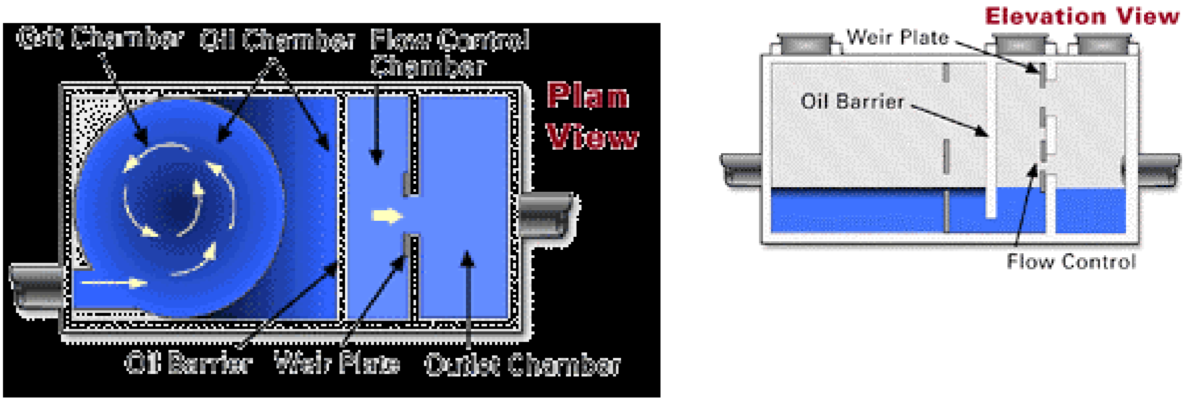

Figure 4.6: Vortechnics Inc. Stormwater Treatment System

Installations of Vortex separators include the largest Storm King installation is at the Columbus, Ohio Uptown Park Water Reclamation centre. A Vortex installation in Seabrook, New Hampshire discharges to a salt water marsh, and protects clam beds in a nearby harbour. Stormceptor systems, comprised of a deep manhole with a baffle insert which induces vortex flow and separates the manhole into a settling zone and a bypass overflow zone, have been installed throughout the U.S. and Canada [http://www.csrstormceptor.com/ and http://www.wateronline.com/].

A proprietary system, Stormtreat, combines solids removal with wetland treatment [http://www.stormtreat.com]. Inlet catch basins are fitted with grit filter bags to trap larger floatables, then flow is directed to sedimentation chambers fitted with skimmers, then to a gravel filter feeding a constructed wetland. From the wetland, flow enters a gravel bed which acts as a reservoir during higher flow, and allows infiltration into the subsoil.

In Houston, Texas, three facilities consisting of chlorination tanks using sodium hypochlorite for odour control, circular clarifiers for storage, solids and floatables removal, and outlet bar screens, followed by a natural bayou, have been installed for combined sewer overflow treatment. Clarifier underflow is either pumped or gravity drained to the sanitary sewer. The facilities were designed for a 2 year storm.

Wastewater

The 1996 US EPA needs survey stated that 190 million people, 73% of the US population, are served by 16,024 wastewater treatment facilities. Seventy one (71) % of the facilities are in small communities with populations less than 10,0000. Only 1% provide less than secondary treatment. (WET Newswatch Feb. 1998).

The 1996 Canadian Municipal Use Database states that 72% of the Canadian population is served by central wastewater treatment. (Note the survey does not contact 15% of the population in centres with less than 1000 pop.). Of those surveyed centres with treatment, 23.8% have primary treatment, 32.2% have secondary treatment, and 44% have tertiary treatment.

Preliminary treatment

Design philosophy now focuses on the removal of rags and floatables from wastewater rather than grinding, since screenings tend to be relatively non-biodegradeable and persist through the process. Therefore, comminutors are not usually specified anymore, especially in larger plants.

Mechanically cleaned coarse screens (greater than 6 mm openings) of varying types are used, with reciprocating rake types presently most popular. The trend is towards maximum screen openings of 13 mm to prevent plastics passing sideways through the bars. A trash rack may be placed upstream of the mechanical screens if the system is fed by a combined sewer. Manually cleaned screens are not generally specified except as protection in unused bypass channels.

Screenings are generally dewatered before disposal to reduce hauling costs. Various types of auger and press type dewatering machines are available.

Grit removal is standard practice, with aerated grit chambers used frequently. Grit removal from the chamber is effected by chain and bucket collectors, screw augers, clamshell buckets, recessed impeller pumps, or air lift pumps. Square unaerated detritus tanks are also used, complete with bottom rakes and grit augers. Vortex grit removal systems are becoming more popular because of their efficiency at removing finer grits at reasonable cost (WEF Manual No. 8). Mechanically induced vortex systems have been installed in large scale. Hydrocyclone systems (Teacup) which rely on head loss to generate a vortex are available up to 7.6 MLD for individual systems.

Captured grit is generally washed and dewatered before hauling to landfill for disposal. Methods include hydrocylones and various types of dewatering conveyors including paddle and cleated belt. Cleated belt dewatering conveyors tend to capture more and finer grit than the paddle types.

Equalization

Flow equalization is not generally considered economical for new plants treating flow from separate sanitary sewers with little infiltration and inflow and little industrial waste, but it is a useful tool for upgrading of existing facilities where the upstream sewer system has insufficient capacity to act as a buffer. Stored flows have usually undergone preliminary treatment to prevent buildup in the equalization tank, and the tank itself will be mixed and aerated.

Primary treatment

Sedimentation is the most common form of primary treatment. Circular tanks are currently most popular due to lower capital cost per unit surface area, followed by rectangular tanks. Square tanks are rarely used due to the difficulty of removing sludge from the corners. Stacked tanks are used where space is a problem, as at the Deer Island treatment facility in Boston, Massachusetts, and in Mamaroneck, New York.

Submerged launders are gaining popularity as an odour control measure. Wind protection is an issue in some areas, as in Milford, Iowa, to prevent surface currents. Scum collection equipment is heated in extremely cold areas to prevent ice formation. Two types of scum collection equipment are typically used, tilting trough and sloping beach. In warmer climates, sludge is withdrawn at higher rates in more dilute form to prevent septicity and solubilization, which can affect plant effluent quality.

Chain and flight sludge collection equipment is now constructed of plastic and fibreglass. Plow type collectors are used in circular tanks, and suction types are avoided on primary sludge due to clogging. Travelling bridge collectors on rectangular tanks cannot be used if the tank must be covered for odour control.

Preaeration enhances primary settling by promoting flocculation. Aerated grit chambers can perform this function. A Water Environment Federation survey of over 1000 treatment plants found that 29 percent use preaeration (Water Environment Federation; see 4.10 Sources of information). Some plants use chemical addition to enhance primary sedimentation. Iron salts are used in several cities in Michigan and at California's Hyperion plant, aluminum salts in Maysville, Ohio and Milan, Michigan, and lime at Martinez, California. Lime is not used often due to higher sludge production and chemical handling difficulties. Chemical coagulation allows operation of tanks with higher overflow rates, thus requiring smaller amounts of tankage.

Thickening in the primary clarifier is generally only practiced at lower overflow rates to prevent scouring of the sludge blanket at higher flows. Co-thickening with Waste Activated Sludge (WAS) in the primary clarifiers is practiced, again at low overflow rates, in moderate climates.

Fine screens are sometimes used in lieu of primary treatment, but removal efficiencies are lower. Of over 1000 treatment plants responding to 1989 WPCF survey, 6 percent used fine screens. Types of screens used include inclined self cleaning static, rotary drum and rotary disk. Hot water sprays are required for cleaning of grease buildup, especially in colder climates.

Secondary treatment

Secondary treatment is the minimal level of treatment required throughout much of North America. Lagoon systems are in use in larger communities only when these are fairly remote, for example, Whitehorse in the Yukon, and where surrounding property values are low. For the most part, secondary treatment for large communities involves some form of mechanical treatment.

Fixed film processes (Attached growth processes)

In a 1984 survey, there were over 2400 trickling filter systems in the United States, approximately half as many as activated sludge plants. Design trends to maximize performance include power ventilation and daily hydraulic flushing to control sloughing and clean the media. Recirculation of effluent also improves quality. Fine screens are used upstream to reduce media fouling, as at South Bend, Indiana, and Sausalito, California. Synthetic media is now often used, although structural failure of the plastic has been an issue in some locations requiring careful selection of manufacturers. These systems are often upgraded with an add-on suspended growth unit process, in a configuration known as TFSC (Trickling Filter – Solids Contact). The trickling filter provides coarse BOD removal and the solids contact tank provides the digestion capacity of the adsorbed and absorbed organic material. TFSC systems are also being constructed as new facilities where ammonia nitrification is not a key parameter of concern.

Rotating Biological Contactors (RBCs) are fairly common in both Canada and the US for small to medium sized communities. Problems with this technology have included performance below design expectations, structural problems with shafts and media, excessive biomass buildup, and uneven shaft rotation for air driven units. Self aligning bearings, increasing the size of the first stage based on total organic loading, allowing for deteriorating performance below 13^{o} C., and using more air for air driven units than indicated by the manufacturer, as well as improvements in shaft design, have addressed many of these problems. A new technology development has been 85% submergence of the rotor.

Both trickling filters and rotating biological contactors are usually covered for odour and vector (fly) control.

Submerged granular media upflow filters known as biological aerated filters are a recent entry in the area of wastewater treatment in North America. Manufacturers include:
Biofor [http://www.enquip.com/biofor.html],
ColOX [http://www.tetraprocesstec.com/technologies/Colox_bioreactors/]
and Biostyr [http://krugerworld.com/USA/].

Suspended growth processes

Suspended growth processes are the most extensively used secondary treatment option, based upon a U.S. EPA 1984 needs survey. Configurations in use include plug flow, complete mix, oxidation ditch, deep shaft, pure oxygen, and sequencing batch reactors. Fine bubble aeration systems are generally preferred over coarse bubble due to energy savings from higher oxygen transfer efficiency.

Designers are moving away from complete mix activated sludge believing that it promotes filamentous bacteria growth. However, many designs are adding selector tanks upstream of the main aerobic process to help prevent growth of filamentous organisms. Conventional plug flow activated sludge plants which can be converted for nutrient removal are now favoured for larger plants. Step feeding and tapered aeration help control the food and dissolved oxygen concentration along a basin length. Contact stabilization is used for wastes with BOD primarily in suspended form.

Oxidation ditches are more popular for smaller plants, (5000 to 50,000 PE's,) with over 9000 constructed in the U.S. Besides the usual oval configuration, vertical loop reactors and proprietary systems such as the "Orbal", and "Carrousel" have been developed. Phased isolation ditches are a combination of oxidation ditch and SBR technology imported from Denmark. There are only two Deep Shaft treatment plants operating in the US.

In the early 1980s there was some interest in pure oxygen activated sludge treatment plants, with over 240 systems operating in the U.S. by 1984. There is little evidence to substantiate the process performance gains from such systems to offset the increased capital cost of oxygen generation. In industrial applications, a key advantage which has been recognized is the reduced amount of offgas and the control of volatile organic compounds and odours into the atmosphere.

Sequencing batch reactors are popular for smaller plants; and there are over 200 SBR's in operation in the U.S. The Intermittent Decanted Extended Aeration System (IDEAS) imported from Australia is also in use. Most of these plants (80%) are for flows less than 4 MLD.
A US developed process, PACT, uses activated carbon addition in the aeration basis. Tertiary filtration and activated carbon regeneration facilities are required. The process is useful in industrial applications.

Hybrid processes

Over 1000 hybrid process plants now operate in the U.S. Hybrid plants are often put into place where an existing system must be upgraded.

Trickling filter plants might be upgraded to an Activated Biofilter, which recycles Return Activated Sludge (RAS) over the filter using plastic or redwood media. This type of system performs well at low organic loads and in warm climates. A example of this technology is the 80 MLD Biocarbone Process located at Sherbrook, Quebec, which is a Swedish technology consisting of a fixed bed reactor in a downflow mode of operation..

Alternatively, a small suspended growth tank can be added downstream of a trickling filter to form a Trickling Filter Solids Contact (TFSC) process. The contact tank is sized for about 10-15 percent of size normally required for activated sludge alone, since the trickling filter removes most of the soluble BOD. Another modification is the roughing filter/activated sludge process, where the trickling filter is a much smaller proportion of the entire process. Separating the two processes with a secondary clarifier is not usually done due to high capital costs when compared to the other processes.

RBC Solids Contact systems are similar to TFSC but use an RBC rather than a Trickling Filter.

Another form of hybrid system submerges inert support media within suspended growth bioreactors. These include the FAST system [http://www.biomicrobics.com], Ringlace [http://www.ringlace.com/presentation], Linpor, and others. Moving Bed Biofilm Reactors (MBBRs) utilize neutral buoyancy media. Fluidized bed reactors are used for industrial wastewater treatment.

Nutrient removal

a. Biological Nutrient Removal (BNR) processes

Nutrient removal has become an important issue along the east coast of the U.S. and in British Columbia, Canada, where nutrients from wastewater adversely affect the environment. Biological nutrient removal has been used in plant designs since 1980 in North America, and offers reduced operating costs by reducing chemical use and power for aeration. Many process configurations are patented and may carry license fees for use, although there are a number of processes which have been placed in the public domain.

It is common practice to include a provision for adding chemicals in the plant design (usually alum) to supplement biological phosphorus removal or for use in the event of a biological upset. Production of volatile fatty acids (VFAs), either by in-stream or side-stream fermentation, is often an integral part of the process, as the bacteria responsible for the excess phosphorus removal require short chain VFAs as a substrate. Most systems now designed are single sludge type, since the extra clarifiers in dual sludge systems increase capital cost.

Most of the suspended growth BNR processes use alternating anaerobic, anoxic and aerobic zones to encourage the growth of bacteria which can store phosphorus. The processes differ in the number and order of the different zones, and the configuration of external and internal recycle flows. Process configurations exist for nitrogen removal only, phosphorus removal only, or both. Common configurations include the A/O process (10 plants), the A2/O process (6 plants), the UCT (or VIP) process (2 plants), modified UCT (4 plants), five stage Bardenpho process (24 plants), and the CNC process (1 plant).

Nitrogen removal processes include the two-stage Wuhrmann or post-denitrification process, the two-stage Ludzack-Ettinger process, and the four stage Bardenpho process.
The Phostrip process is a combination of biological and chemical system which diverts phosphorus rich biomass to an anaerobic tank where stored phosphorus is released, the biomass is returned to the aeration basin, and phosphorus rich supernatant is chemically precipitated before being returned to the process. Seven plants are described in Water Environment Federation (WEF) Manual No. 8. The Phostrip II process is used for combined nitrogen and phosphorus removal.

The Orange Water and Sewer Authority (OWASA) Nitrification process was developed in North Carolina and uses a trickling filter as part of the process stream to reduce oxygen requirements on the aeration system [http://www.owasa.org]. Trickling filters can also be used for nitrification/denitrification. Denitrification filters are designed as deep beds, with methanol dosing. At least three are operating in Florida.

Existing processes which have been successfully adapted for biological nutrient removal are SBRs, oxidation ditches, and trickling filter/solids contact (TF/SC) processes. A quarter of SBRs in operation have been adapted for nutrient removal by simply varying operational modes to allow for a static fill stage to create anoxic conditions. In oxidation ditches, anoxic zones can be allowed to form upstream of the aeration devices. The Orbal system has been used for nitrogen removal successfully at Hartland, Michigan [http://www.cpcwwtcom/index.html]. The Closed Loop Reactor (CLR) process, imported from the Netherlands, has been used for bioP and bioN removal [http://www.lakeside_equipment.com/clr.htm]. TF/SC processes have also been adapted for nutrient removal, as at Salmon Arm in British Columbia Canada. These adaptations, however, typically have sub-optimal nutrient removal characteristics in comparison to the activated sludge suspended growth BNR configurations noted above. Submerged RBCs have been used for denitrification at a facility in Florida.

b. Chemical nutrient removal

Chemicals are added to secondary clarifiers to precipitate phosphorus from the waste stream. Typical chemicals used include lime, alum, sodium aluminate, ferric chloride, and ferrous sulphate. Until the 1980s, all phosphorus removal in North America was achieved through chemical means.

c. Enhanced and constructed wetlands

Rather than upgrade to biological nitrogen removal, some facilities opt to use wetlands as final polishing steps, such as the Riverside California Wetlands Enhancement Project. Wetlands are also used to manage agricultural stormwater runoff, for example at the South Florida Everglades Nutrient Removal Project, a 1619 ha artificial marsh.

Final solids separation

a. Conventional sedimentation

Circular secondary tanks are more popular with designers than rectangular tanks. Newer designs trend towards inboard launders to prevent short circuting and deeper tanks for more positive sludge blanket control flows and hydraulic suction mechanisms are used to remove activated sludge. Computer models are used to optimize existing systems and design larger systems. The BOAT clarifier manufactured in Louisiana is an in-channel clarifier developed for oxidation ditches [http://www.ui-inc.com/boat.htm].

b. High rate sedimentation

High rate sedimentation systems incorporate either internal structures to speed settling and trap solids, or introduce a carrier material (clay) with a high settling velocity. An example of the latter system is the MicroSep system manufactured by U.S. Filter [http://www.cpcwwt.com/micro/tech01.html].

c. Granular media filtration

Final filtration using granular media filters is typically applied where effluent limits are equal to or less than 10 mg/L SS, or where particulate phosphorus must be removed to meet a low total phosphorus TP limit. Gravity filtration is most common in the larger plants, with smaller plants using more pressure units. Most filters operating in the US are downflow units, although there are also some upflow and bioflow filters. Of the single media filters, slow sand filters are in use rather than rapid sand filters, as the latter tend to clog rapidly. Dual and multi-media types are popular due to longer filter runs. Silica sand, anthracite, activated carbon, resin beds, garnet, and ilmenite are used as media. The capability to add coagulating chemicals upstream is usually part of the design.

Continuously backwashing filters include travelling bridge types, moving bed filters, and pulsed bed filters. Air scouring has improved backwashing efficiency.

Activated Carbon final filtration is used to remove refractory organics and inorganic compounds such as nitrogen, sulphides and heavy metals, or to remove soluble organics following physical/chemical treatment.

d. Membrane filtration

Four types of pressure membrane filtration systems are in use in North America; micro, ultra, nano and hyperfiltration (also known as reverse osmosis or RO), with microfiltration being the largest pore size. Microfilters are used to remove bacteria and cysts, colloidal and suspended solids downstream of flocculation, and for RO pretreatment. Ultrafilters can also remove viruses. Nanofilters can also remove large organic molecules, and are used to remove colour hardness and reduce TDS. RO filters can remove ions and are used for desalination, wastewater reuse, food and beverage processing and industrial process water.

Biological fouling prevention in terms of upstream disinfection of the waste stream is commonly practiced. Membrane configurations include tubular, spiral wound, and hollow fine fibre. A example of a hollow fine fiber membrane is the Zenon Environmental Inc. Zeeweed® membrane illustrated in Figure 4.

Disposal of reject brine from membrane systems is often an issue. Methods include deep well injection, evaporation ponds, and evaporation to dryness and crystallization.

Effluent disinfection

a. Chlorination and dechlorination

Chlorine is the most widely used method for wastewater disinfection. Chlorine is available in liquid form in steel containers, and as sodium hypochlorite solution, or calcium hypochlorite in dry form. Dechlorination is mandatory in many areas due to effect on fish populations of chlorine and combine chlorine residuals. Chemicals used for dechlorination include sulfur dioxide, available in liquid form in steel containers, and sulphite salts (sodium bisulphite, sodium metasulphite) used in smaller installations.

Safety is an issue with the above systems. Total containment vessels are available for smaller facilities.

b. Ultra-violet disinfection

More than 1000 wastewater treatment facilities in North America use UV disinfection. Most systems use open channel modular design. Improvements in technology allow use on poorer quality effluent. Pilot testing is used to determine site-specific fouling conditions. Multichannel configurations are used on large systems.

i) Low intensity lamps

An estimated 80 percent of all UV systems in operation are open-channel, low pressure lamp systems, and over 99 percent of all installations use low pressure lamps. Development of the electronic ballast was a significant improvement, allowing modulation of the power supply to the lamps and better flow pacing of UV intensity. Since output intensity is fairly low, relatively large numbers of lamps are required. An example of a low intensity UV system manufactured by a Canadian firm (Trojan Technologies) is shown in Figure 4.7 [http://trojanuv.com/products.html].

ii) Medium intensity lamps

Medium intensity lamps operate at higher lamp pressures and temperatures, and are not affected by wastewater temperature as are low intensity lamps. UV output is 8 to 16 times higher than for low intensity lamps, therefore a smaller installation is possible. Eight medium intensity installations are currently operating. The systems offered provide automatic in-place cleaning.

Medium intensity lamps have been used to control zebra mussels at the Bruce Nuclear Generating Plant in Ontario.

iii) High intensity lamps

Low pressure, high intensity lamps, attempt to produce the high intensity of medium pressure lamps with the monochromatic light of the low intensity lamps. An example of a high intensity variable output UV system manufactured by a Canadian firm (Trojan Technologies) is shown in Figure 4.7.

Figure 4.7: Trojan Technologies Low Pressure (UV 3000) and Variable Output High Intensity (UV 4000) Ultra-Violet Wastewater Disinfection Systems

Sludge management

Which sludge management methods are used often depends on the available end market and disposal options.

a. Pretreatment, storage and transport

Before sludge and scum is processed, it may be pretreated to reduce nuisance factors and wear on downstream machinery. Primary sludge may be further degritted using hydrocylones. In-line grinders have been used to reduce particle size, but more recent practice is to remove nuisance contaminants from the process stream by screening the sludge with in-line auger type wedgewire screening machines. This extra step is usually only warranted if plugging of downstream processes such as heat exchangers is likely. Scum screening using rotary drum screens before transport to stabilization is becoming common.

Sludge storage capacity is provided upstream of sludge management processes to equalize flow to the various types of machinery, especially where a process operates discontinuously. Storage tanks may be aerated and mixed.

Liquid sludge is transported between processes using a variety of pumps. Air operated diaphragm pumps and recessed impeller pumps are favoured for primary sludge pumping. For secondary and digested sludge pumping, solids handling centrifugal pumps, screw impeller pumps, plunger pumps, peristaltic hose pumps, progressive cavity pumps, and rotary lobe pumps are used. Good grit removal is essential upstream of the last two types of pumps to prevent excessive wear and maintenance. Positive displacement pumps are favoured for pumping thickened sludges. Archimedes screw pumps have been used for RAS return, but are not recommended for biological nutrient removal plants. Reciprocating piston pumps are used for pumping thickened sludge cake.

Pipelines for sludge service are typically lined to reduce friction losses and pipe corrosion. Glass lining on digested sludge piping prevents struvite crystal formation. Pipes conveying scum are often heat traced to prevent grease buildup.

Spiral screw conveyors (centreless are favoured depending on loading) and belt conveyors are most often used to transport screenings, dewatered sludge and dried sludge in treatment plants. Drag conveyors, bucket elevators and pneumatic conveyors are also used to transport dried sludge.

b. Conditioning

Both chemical and thermal conditioning are used to improve the efficiency of thickening and dewatering processes.

Chemical conditioners include ferric chloride, lime and organic polymers. Ferric chloride and lime have mostly been used with recessed chamber filter presses and vacuum filters for sludge dewatering. Organic polymers are generally the first choice for thickening because they do not increase sludge volume, do not lower sludge fuel value, and are safer and easier to handle than, for example, lime. Polymer is available in dry or liquid form. Compact computerized mixing and blending units are popular, with variable speed mixers to prevent floc shear. Dosage is determined by jar testing for each individual application. Progressive cavity pumps are a popular choice for dosing.

Both heat treatment and low pressure oxidation are used for thermal conditioning of all types of sludge, but there were only 13 operating heat treatment installations in 1985, and the technology is no longer marketed in North America. In 1985, there were 75 low pressure oxidation installations. High strength side streams are provided with separate biological treatment, and since the stream is warm, anaerobic treatment is effective. Well trained maintenance personnel and operators are necessary for safe and efficient operation.

c. Thickening

The simplest form of thickening operation, used mainly for smaller plant operations, is co-thickening of both primary and secondary sludge in the primary clarifiers. This process is more successful with attached growth processes, and with clarifiers with floor slopes greater than 12:1. For success, the operation of the primary clarifier should be carefully monitored.

Separate gravity thickening in circular tanks is mainly used for thickening of primary sludge, combined primary and secondary sludge, and lime sludges. It is usually the most economical option for primary sludge thickening. Present practice allows for a dilution water supply to maintain aerobic conditions, and polymer is seldom used.

Gravity belt thickening is gaining in popularity for thickening of all types of solids because of low space needs, low power use, and moderate capital cost. The process requires conditioning, usually with polymer. Gravity belt thickeners are relatively simple to operate and produce good results with little operator attention.

Rotary drum thickeners are used in small to medium sized plants for waste activated sludge thickening. Polymer use is high, but the process requires relatively little space, has low power usage, moderate capital cost and is easy to enclose. Pilot testing is often done to determine process applicability in a given situation.

Dissolved air floatation (DAF) thickening is used for secondary sludges, including those from smaller plants with no primary clarifiers, and for aerobically digested sludge. Polymer is generally used to allow higher loading rates and solids capture. DAF processes are usually operated continuously.

Centrifuges are used for thickening secondary sludge. Solid-bowl conveyor centrifuges are the preferred type, with pool depths inside the centrifuge increasing. Polymer addition allows increase of hydraulic loading. A heated water supply for periodic flushing is recommended, and progressive cavity pumps are used for feed for good control.

d. Sludge stabilization

Sludge stabilization is practiced to reduce mass and volume requiring disposal and to increase the aesthetic value of the resulting biosolids by reducing vector attraction and pathogen content. The four most common sludge stabilization methods are anaerobic digestion, aerobic digestion, composting, and alkaline stabilization. Other types of stabilization include fermentation, sludge to oil systems and combustion

i) Anaerobic digestion

Anaerobic digestion is likely the most widely used stabilization method, and is almost always preferred for plants greater than 19 ML/d. The process is relatively complex and tends to upset if not managed by competent operators. Most new systems are high rate, with heating and auxiliary mixing. Recuperative thickening has been used to maximize process tankage capability (Seattle West Point).

A common tank configuration is a low vertical cylinder with a cone-shaped floor and fixed, floating or gas holder cover. New installations may have waffle bottoms. Egg shaped digesters are also now being constructed, and there are at least 16 installations in North America. Mixing is accomplished by gas mixing, mechanical mixing or pumping, or a combination. Confined gas-injection systems using draft tubes are common, and multiple-drop lance type mixing is also popular. Rotary lobe, rotary vane and liquid ring gas compressors are used. Mechanical mixers are generally propeller or turbine type mounted in external draft tubes.

Methane gas produced is often used as fuel for digester and plant heating. Larger installations often install cogeneration plants for increased power savings. Surplus digester gas has been upgraded and sold to gas utilities in such cities as Seattle, Washington and Phoenix, Arizona. Scrubbing is required to remove hydrogen sulfide. The liquid redox process was successfully used for this purpose at the Los Angeles Hyperion plant.

Anaerobic digestion is most often operated in the mesophilic temperature range, but thermophilic operations have been initiated to take advantage of pathogen free sludge production. There are at least three full scale thermophilic anaerobic digestion operations in North America. Temperature phased operations, with one stage mesophilic and the other stage thermophilic has been tried at several installations. (Woodridge Greenvalley WWTP, DuPage County Illinois (unmixed Acimet system) Newton Iowa, Omaha Nebraska).

Struvite control may be an operational problem, particularly where phosphorus is removed through either chemical precipitation, or where biological nutrient removal (BNR) sludge is subjected to anaerobic treatment.

ii) Aerobic digestion

Aerobic digestion is more often used in smaller plants with flows less than 19 ML/d. It is a less complex process with lower capital cost, although more power intensive.

Mesophilic aerobic digestion tankage is usually open, unless high purity oxygen is used. Both mechanical surface aerators and either fine or coarse bubble diffused aeration may be used. The process is also used in northern communities, although with longer retention times.

Auto-Thermophilic aerobic digestion (ATAD) has been used since the 1980s in North America. It has become more popular due to a pathogen free biosolid product, reduced tankage size, and no external heating requirements. The most common type of aeration are aspirating aerators, although venturi pump systems and turbines with diffused air have also been used. One of the first installations in North America was constructed in Banff, Alberta, Canada.

A variation of thermophilic aerobic digestion, deep well wet air oxidation, was demonstrated at the Renton WWTP in 1997.

Dual digestion uses an ATAD as a first stage for pasteurization, followed by mesophilic anaerobic digestion. Lebanon, Tennessee was the first USA application of this dual digestion process (Schafer et al., 1994). The concept behind dual digestion is to destroy pathogens before anaerobic digestion/stabilization.

iii) Composting

In 1993, there were 207 sludge composting projects in the US in operation and under construction, producing biosolids for use as soil amendment. About 50 percent are static pile, with the remainder split between windrow and in-vessel methods. Operation for pathogen reduction is an issue to increase final market options. Methods usually allow for 21 days of active composting followed by 30 days of unaerated curing. There are as yet no standards for determining degree of compost maturity. In Canada there are more than 33 biosolids composting facilities, with 14 of these in Quebec and 7 in New Brunswick.

The aerated static pile method was developed in the U.S. Wood chips are the most common bulking agent used, and screening and recovery of the bulking agent may be practiced. Covered facilities are preferable for water and odour control.

In-vessel systems are vertical plug flow reactors (3 major types in use in US), horizontal plug flow reactors (tunnels), and agitated bin reactors (long open bins, and circular vessels). Multiple temperature probes aid process control. In-vessel composting operations have had varied levels of success, with the biggest problem being marketing/sales of the compost end-product in some areas. There have also been problems noted with certain processes, such as the structural failure of the concrete walls of a tunnel reactor system located near Portland, Oregon, USA, several years ago.

iv) Lime stabilization

The USEPA 1988 Needs Survey identified more than 250 plants using lime stabilization. Lime stabilization is used to produce soil amendment, and is a simple process compared to digestion and composting. It is reliable, has low capital cost, is compact, and easy to operate. However, the lime used is expensive, and increases the bulk of solids to be handled, which is why the process is more usually used for small facilities, or as an interim process to back up another stabilization process at a larger plant. If the product pH drops, the biosolids produced can become unstable. Other additives can be used instead of lime; mostly cement process derivatives such as kiln dust and fly ash.

Liquid lime stabilization is used mainly in smaller plants or at locations with short hauling distances to final disposal. Dry lime stabilization is used at both small and larger plants. In both cases, pilot scale testing is advised to determine correct lime dosages in a given situation. Dust control must be addressed in design.

Lime stabilization is also carried out in conjunction with the application of heat, or acid to generate heat, to ensure pathogen destruction.

v) Fermentation

Fermentation is used to produce volatile fatty acids required for biological nutrient removal. It has been accomplished in modified gravity thickeners (Kelowna B.C.) as well as specially designed, sealed mixed tanks (Bonnybrook, Calgary, Alberta). These fermenters have been designed as single vessel reactors (eg. Penticton, British Columbia), and in conjunction with gravity thickeners (eg. Kalispell, Montana).

A separate high temperature fermentation process has been developed for stabilization only, with the objective of producing a saleable byproduct as feed.

vi) Submerged combustion

Submerged combustion directly contacts sludge with the products of gas combustion. Spiral heat exchangers are used for heat recovery and prewarming of cold sludge. The first facility (manufactured by a Canadian firm Inproheat Industries of Vancouver, British Columbia) built is operating in Monticello, Minnesota, used as a pre-treatment stage before anaerobic digestion (similar to the dual digestion process configuration described earlier) to ensure sludge pasteurization [http://www.inproheat.com/]. The patented submerged combustion technology, called SubCom, injects hot gases into the sludge to kill pathogens. Cold activated sludge enters the Inproheat SubCom system at 10 °C (50 ^{o}F) and passes through an Alfa Laval spiral sludge to sludge heat exchanger with an outlet temperature of 46.1 °C (115 ^{o}F). The sludge then enters the submerged combustion heating unit where it is heated to 70 °C (158 ^{o}F) and passed to the internal flow-through tank retention compartment. Moyno progressing cavity pumps with variable frequency control are used to maintain the level in the retention compartment and pump the sludge out of the tank, through the Alfa Laval spiral heat exchanger and to the anaerobic digesters. The system is intended to operate 7 hours per day with a continuous sludge flow of 65 USGPM. The anaerobic digestion stage then stabilizes the sludge by reducing the volatile solids content.

e) Dewatering

The two mechanical technologies most commonly used for dewatering are centrifuges and belt filter presses, with the choice being generally site specific. In all cases, pilot scale testing is recommended to optimize design.

Centrifuge dewatering is used successfully on many different types of sludges. Solid bowl centrifuges are presently used, with both countercurrent flow and concurrent flow. Newer high solids machines can produce greater than 30% solids reliably, and abrasion resistant materials prolong machine part life. Organic polymers are preferred for conditioning since they are more cost effective and have better maintenance, performance and safety records than other types of chemicals. If dewatering anaerobically digested sludge, allowance must be made for struvite formation in the centrate handling system: ferric chloride addition has been used. Electrical control interlocks with the feed system are important for efficient operation.

Belt filter presses have reduced energy requirements when compared with centrifuges and vacuum filter, but generally produce lower solids concentrations than high solids centrifuges. Polymer is used for pre-conditioning, and feed concentration should be as consistent as possible. Upstream grinders improve belt life, and rubber coatings on rollers are preferred. Most units, greater than 80%, are 1 m or 2 m belt widths.

Rotating Vacuum Filters are a technology introduced from England, consisting of a vacuum drum covered with a filter material and partially submerged in a tank of sludge. Pressure filter presses produce a drier cake than belt filter presses, can be used for a wide range of solids, and produce high filtrate quality. Partial automation makes filter presses more attractive than formerly, but they are still not as popular as vacuum filters, centrifuges and belt presses due to high capital cost, high conditioning costs, and relatively high operations and maintenance costs. Typical applications include landfill disposal and incinerator disposal where drier cakes are important. Precoating of filter using cement process dusts aids cake release and filter cleaning. A recent variation used in Toronto, Ontario, pumps hot water through the plates and pulls a vacuum to produce a very dry cake.

Rapid gravity beds are simple machines that have been used for septage dewatering. They consist of a static wedgewire screen mounted on an angle in a hydraulically operated dumping bed. The batch process uses polymer and is simple to operate for smaller communities.

Drying beds are generally used in small facilities and in the southwestern US, but can be designed for all plant sizes and for widely varying climates, although freezing can deactivate a bed during the winter months. They are more labour intensive than mechanical dewatering methods and require more land. Covered beds provide temperature and precipitation control, but open beds offer better evaporation if the weather conditions are favourable. Beds must be lined and groundwater monitoring is often required by the local authorities. Paving has been used, including heated paving in Dunedin, Florida. Other variations include vacuum assisted drying beds, and wedge-wire beds. This dewatering method can also be used as a pathogen control method in conjunction with anaerobic digestion.

Another variation on drying beds involves planting reeds in the drying beds and harvesting them annually. The method has been used in Indiana, Wisconsin, New York Pennsylvania, and Maine for plants with less than 7.5 ML/d flow. Climate should ensure at least one prolonged frost during the winter. Sludge is generally removed from the beds every 10 years.

Dewatering lagoons in warmer arid climates give the best results, but they have also been used in wetter, colder climates (i.e.Vancouver, and Winnipeg, Canada). This is a slow process, requiring 1 to 3 years.

f) Thermal drying

Sludge drying is used as a pretreatment step for composting, alkaline stabilization or incineration, or, if dried to 90 percent solids or higher, for direct land application. Dust control is important in these installations due to fire and explosion hazard, as is air pollution control equipment. Use of alternative fuels, such as digester gas, can reduce operating costs.

Direct sludge drying systems are the most common in North America. Rotary dryers have been successful at several facilities in the US and in Canada. There are approximately five flash drying installations in the US; most others have been shut down due to high energy and operations and maintenance costs, as well as fires. One fluidized bed direct dryer is operating in Mattebassett, Connecticutt.

Use of indirect dryers is limited in the U.S. There is one installation of horizontal indirect dryers at the Hyperion treatment plant in Los Angeles, and one installation on the east coast as well. There is a vertical indirect drying system at the Back Water plant in Baltimore.

Combination of direct and indirect dryers are operating at the Jones plant in Milwaukee. Their product, Milorganite, is distributed over North America as soil amendment in garden stores.

g) Incineration

Incineration is used throughout North America. It is generally economical for plants with flows greater than 38 ML/d. Fluidized bed incinerators are more popular now, and are used for plants between 38 and 76 ML/d. Multiple hearth incinerators are feasible for plants with flows larger than 76 ML/d. (WEFTEC 95, Lundberg et. al. 1995) There are seven existing infrared or electric incinerators in operation, but they are not currently being marketed for new installations due to mechanical problems and high electricity costs.

There were at least 15 fluidized bed incinerators in operation, and at least 38 multiple hearth facilities in operation in 1983. At least half of the multiple hearth installations are over 20 years old. Their age has led to air pollution control issues with new discharge regulations requiring upgrading and continuous monitoring of stack emissions.

Air pollution devices for particulate control include mechanical collectors (settling chambers, impingement separators, cyclone separators), wet scrubbers (spray tower, cyclone scrubber, ejector-venturi scrubber, venturi scrubber) and dry electrostatic precipitators. Bag houses are used if the gas temperature is reliably reduced by a heat recovery boiler.

Odour control

Control of odours from wastewater treatment plants is becoming more of an issue as communities grow to surround what were once isolated locations. Odour complaints have escalated to lawsuits against wastewater treatment plant and composting facility operators, even closing some operations. Headworks and sludge management facilities are the biggest odour sources, with fixed film processes also being a problem.

Reduction in liquid turbulence by reducing length of water drops over weirs and using submerged weirs, as well as good housekeeping, is used to control odours. Addition of chemicals such as chlorine, hydrogen peroxide, and ferric, ferrous, or zinc salts to the wastewater stream upstream of the headworks is practiced to reduce and control odours. Frequent withdrawal of sludge from settling tanks can also reduce odours from those sources. Covering odour sources such as trickling filters with aluminum or fibreglass covers and venting air to a central foul air treatment facility is also practiced.

Foul air treatment includes scrubbing with water, plant effluent, and chemicals such as potassium permanganate, sodium hypochlorite, caustic, hydrogen peroxide, chlorine and chlorine dioxide. Biofiltration using woodchips or compost, and activated carbon filtration is used. For very strong foul air streams such as from sludge heat treatment, regenerative oxidation is used.

Use of enclosed methods of conveying sludge such as screw conveyors and piston pumps rather than belt conveyors reduces odour generation. Centrifuges contain odours, while belt filter presses and gravity belt thickeners require encasement and venting of foul air to central treatment. Composting facilities are high odour generators, with the trend in new facilities being to contain the odour sources and vent to a treatment facility, generally scrubbers or biofilters.

Masking agents have been used as short term measures, but meet with mixed success and are not recommended where the odourous gas is also hazardous, i.e. hydrogen sulphide.

Release of volatile organic compounds from treatment works has become an issue in the United States.

Computer control

Central computer control systems and distributed control systems (Supervisory Control and Data Acquisition, SCADA) are being increasingly installed in wastewater treatment plants for monitoring, control and optimization of the process. The systems reduce plant staffing requirements, especially in small to medium sized plants where multiple daily shifts can be eliminated.

Distributed control systems, with a central processing unit in a central control room processing data from process control centres around the plant, and from local processing units by each process, are generally used. Remote alarms can be monitored and responded to by lap-top computer and modem. Data from on-line sensors, such as dissolved oxygen monitors in aeration basins, can be used to control equipment such as blowers. Equipment can be started and stopped using the computer control system. Redundancy is built into the control system to guard against computer downtime. Historical operating data is automatically recorded and available for analysis. Plant lab data is entered into the system. Expert systems can be built into the software as a troubleshooting tool for operators.

4.4 Reuse (Topic d)

Wastewater reuse is an issue in arid regions, and in other areas where water costs are high. In 1993 the USEPA developed a guide for wastewater reuse. Many states and provinces now have specific guidelines for reuse of reclaimed wastewater, with the standards and criteria set in California being considered the most stringent and progressive.

A standard reuse of wastewater is as utility water for the wastewater treatment plant which produced it, especially for larger plants. The chlorinated effluent water is used for washdown and for irrigation of the treatment plant grounds, to save city water charges.

Irrigation methods are discussed under topic e, as they are also a disposal method. Irrigation of golf courses, grassed playing fields, and highway medians using treated wastewater is common in many arid and semi-arid areas of North America.

Large scale groundwater recharge is practiced in California, New Jersey and Georgia. Orange County in California injects reclaimed water to prevent saltwater intrusion to the local aquifer. Los Angeles has practiced surface spreading to recharge local aquifers since the 1960s. The City of Perth Amboy, NJ, operates two open water recharge reservoirs to supplement the local drinking water aquifer and to prevent salt water intrusion. Clayton, County in George applies reclaimed wastewater to its potable water watershed.

Wastewater is also reused by industries. In Texas, the Southwestern Public Service Company of Amarillo Texas, operating gas fired steam generation electric power stations, has used treated wastewater in its cooling towers since 1971. Blowdown water from the cooling towers is used on local grazing land for irrigation.
Dual plumbing systems reuse treated wastewater for non-potable purposes. At the Las Vegas Treasure Island Resort Hotel, graywater mixed with groundwater is treated with activated carbon, straining, preliminary disinfection, polymer dosage, pressure filtration, reverse osmosis and UV disinfection before being used to supply the hotel's "pirate sea". In Toronto, Ontario, the Healthy House, a demonstration project, treats septic tank effluent with a Waterloo Biofilter, multi-media sandfilters and ozonation and reuses the product for laundry, toilets, baths and showers. At the Sandy Hill cooperative housing project, part of the communal greywater is screened and treated with ozone for reuse for toilet flushing in apartments. (Jowatt and Pask 1997). Many states and provinces now have Plumbing Codes that permit dual plumbing (potable and non-potable) systems that enable wastewater to be reused for flushing toilets and urinals.

There are also instances of reuse as drinking water. Since 1978, Upper Occaquan Sewage Authority in Alexandria, Va., has been blending 75.7 million L/d of repurified water into a reservoir before being converted to potable water.

In San Diego, California, a wastewater effluent project was conceptually approved for construction by the California State Department of Health Services, which would discharge reuse treated wastewater into the City's watershed for use as drinking water. A water reclamation plant presently provides up to 10.7 million m^3 /year of reclaimed wastewater for landscape irrigation and other non-potable uses. By 2004, up to 18.5 million m^3 you would have been further treated in a water repurification plant for human consumption. The process included micro-filtration, reverse osmosis, nitrate removal by ion exchange, and ozonation. (Richman 1997). However, the City Council suspended the project in January, 1999 and is now looking at other alternatives.

Another reuse project in Tampa Bay, Florida, which was also carefully researched and pilot tested, was recently shelved in March, 1998 due to difficulty building public consensus in several political jurisdictions, and the availability of new desalination technology.

http://www.dwr.ehnr.state.nc.us/reports/reuse/reuse.htm

4.5 Disposal (Topic e)

4.5.1 Land disposal of liquid effluent

Land based disposal is practiced for individual homes not connected to central treatment systems, and for some small communities with sufficient available land. In more agricultural areas, most homes will use soil absorption systems. In 1986, 20,900,000 soil absorption systems were operating in the U.S. (WEF Manual of Practice No. 8).

Conventional gravel trench systems are typically used for wastewater flows of 190 m^3/d or less.

Where site conditions mandate, a variety of technology modifications have been developed. Deep absorption trenches are used where a shallow impermeable layer exists in the soil with a more permeable layer below, and the groundwater level is low. Elevated drain fields are used where the permeable layer or groundwater table is less than the depth required by local regulation. The "at grade" system is the upper extent of elevated drain fields, where the bottom of the trench aggregate is located on tilled soil surface. Sand lined beds and fill systems, referred to as built-up mound systems (see Figure 4.8) are used above shallow fractured bedrock or high permeability soil. Mound systems were developed at the University of Wisconsin (Wisconsin Mounds) and have found wide use across North America where there is high groundwater, a shallow impervious layer, low permeability soil, or a shallow soil profile. This is essentially a variation on conventional gravel trench systems where a sand mound is built above grade and trenches are installed in the sand. Careful design and construction practices must be followed if the system is designed for more than 24 homes.

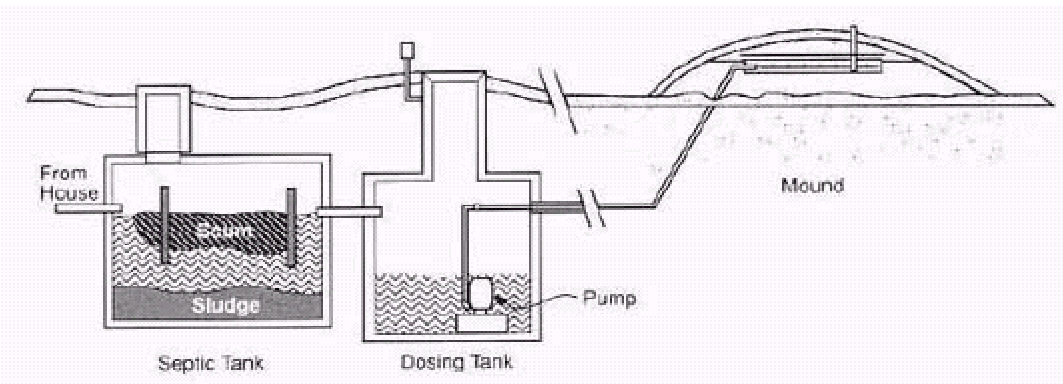

Figure 4.8: Mound System

Contour trenching systems, developed in Nova Scotia, Canada, are used where slopes are steep (i.e. ski hills), and where soils have low permeability. A single trench is run along a slope contour, stretching out the drain field over one long run so that the hydraulic flux to the soil is minimized and spread over a large cross sectional area of soil. Although smaller systems may dose by gravity, larger systems are typically pressure dosed.

For all trench style systems, pressure dosing is being encouraged as prolonging the life of the drainfield. Gravity flow, using distribution boxes, is still used for smaller systems as it is less expensive.

Chamber leaching systems are plastic arched chambers installed underground, which provide a large storage volume in the trenches to handle peak flows. This technology replaces conventional gravel filled trench technology. Wastewater percolates through the trench bottom, which is open, and through openings in the chamber sidewalls. Storage volume in the trenches is not lost over time, as can happen with gravel filled trenches. Several areas in North America (ie: Maine, Texas) allow leachfields using chambers to be sized at 50 to 60 percent of the effective area required for gravel leaching systems. Other areas are testing the systems and considering changes in local regulations. Over 350,000 chamber leaching systems are in use.

Irrigation using wastewater as a disposal method is mainly practiced in the more arid regions of North America, as freezing is a concern with these systems. Sufficient storage for wet and cold seasons must be provided. Pasture, forest, row and field crops have been irrigated using wastewater. The type of crop grown, location, and public access affect the level of upstream treatment and disinfection applied.
Upstream secondary treatment and disinfection is generally required for above ground systems; flood irrigation, spray irrigation, and furrow irrigation (also known as slow rate land application). Only where the application location is isolated with restricted public access and the intended crop is not for human consumption is primary treatment only recommended. Sprinkle irrigation is not recommended for above-ground food crops. Frequently a buffer zone is provided around a spray irrigation site to allow for drifts of aerosols.

Shallow irrigation systems were developed in North Carolina, and consist of a buried distribution system shallow enough that water is available to plants. No more than primary treatment is required upstream, but root crops grown for human consumption should not be the irrigated crop.

Drip irrigation systems consist of a pressure dosing pump, backwashable filter, flow meter, Process Logic Controller (PLC), drip irrigation lines, and valves on each lateral to control flow. Drip emitters may be pressure compensating or non-pressure compensating. Some designers consider that upstream disinfection is also necessary to prevent plugging of such systems (Perkins, 1989). Sites with slopes up to 45% have been serviced in this manner.

Rapid infiltration beds consist of shallow spreading basins in permeable soils to which wastewater is intermittently applied and discharges either to groundwater or to underdrains. Deep permeable soils are required. Upstream aerobic and facultative lagoons are not recommended unless effluent suspended solids are controlled, as algae from the lagoons can clog the infiltration surfaces.

Evapotranspiration beds can be installed where there is net positive annual evaporation. They are used where there is high ground water, a low permeability soil, shallow fractured bedrock, or percolation is disallowed by a regulatory agency.

Liquid effluent disposal to rivers and ocean

Disposal to natural wetlands is generally only used after secondary treatment and possibly also tertiary treatment such as polishing in a constructed wetland. A high level of treatment is required to avoid damaging the natural ecosystem. The Northwest Regional Wastewater Treatment Facility in Seminole County, Florida uses natural wetland effluent disposal, as well as reclaimed water irrigation and rapid infiltration basins.

Outfall discharges are the most common method of disposal for communities located near a surface water source such as a river, lake or ocean. Design of new outfalls generally requires detailed current analysis, water temperature and salinity stratigraphy, as well as hydraulic and plume modelling. Most main outfalls in lakes or ocean environments are installed below a minimum depth to prevent surfacing of effluent.

Overflows from older combined sewer systems, originally intended to operate intermittently under extreme storm conditions, have proven to be a problem in maintaining receiving body water quality throughout North America. Most of the combined sewer overflows (CSOs) are located in large communities: for example of the 13,000 CSOs along the Ohio River, more than 75% of discharges are from 10 large cities. (WET Mar. 1998, Shamsi, U.M. "Thinking Small")
Overflows from the systems have become more common as communities have grown, and have become less acceptable as standards of environmental protection have risen. Combined sewer overflow control is now required in the United States, and communities are required by the US EPA to produce plans to reduce CSOs and remove floatable and suspended solids from such flows before discharge. Most older communities in North America are presently dealing with this problem, largely through the elimination of CSOs through sewer separation.

Sludge disposal

Increased cost of traditional sludge disposal options, especially landfilling, plus increased encouragement from the US EPA have substantially increased beneficial reuse of treated sewage sludge (biosolids) in the U.S. Regulation changes, such as prohibition of ocean dumping of sludge, has provoked cities such as New York to search for other options. The dumping of sludge into the ocean falls under provincial jurisdiction in Canada, and is not allowed in most provinces. Although beneficial reuse is encouraged, if lower cost options present themselves and are allowable by local regulation, they are generally taken. For example, dramatic declines in landfill transport and tipping fees in Philadelphia, Pennsylvania caused that city to change from nearly 100% beneficial use (land application and composting), to almost 50% landfilling.

Of the over 6.8 million dry tons/y of biosolids produced in the U.S., 55% is land applied, 19% is surface disposed including co-landfilling with solid waste, monofilling and permanent disposal in piles or lagoons, 17 % is incinerated, and 9% is either in long term storage such as in wastewater treatment ponds, or is hauled to other states for mostly land application and surface disposal. (derived from data in Bastian, 1997)

Land application

Land application includes application of liquid, dewatered cake, dried, composted, alkaline stabilized or otherwise processed product to cropland, forests, reclamation sites, and lands as organic fertilizer or soil amendments, or used in potting mixes and the production of topsoil, including daily or final landfill cover. Prevention of aesthetic problems, mainly odours, truck traffic and dust, is important for acceptability of a land application program.

Distribution and marketing of biosolids is now a big issue. Compost has been used for potting and horticultural mixes for green houses, nurseries and retail, soil replacement at field nurseries and sod farms, blending to produce topsoil, turf establishment at new developments, top dressing for golf courses and other institutions, land reclamation at landfills, mine and gravel pit operations, and landfill cover. Forest application of biosolids is practiced in Washington State and British Columbia.

Where sludge has been applied in excess of agronomic rates and no crop is grown, for example at reclamation sites, the method is called "dedicated land disposal".

Landfilling

Dewatered and dried sewage sludge is disposed of to both dedicated municipal sewage sludge landfills, and co-disposed with municipal solid waste. Sewage sludge monofills in the U.S. must meet strict siting criteria to prevent environmental impact, and must be provided with leachate and gas migration control.

4.6 Policy and institutional framework (Topic f)

Policies

The primary regulatory policy is the protection of public health to reduce human disease. Therefore, higher levels of treatment are generally required with an increasing likelihood of human contact with plant effluent or biosolids. In North America this policy is taken for granted, resulting in concentration on the next priority objective, which is environmental protection.

Reducing the effect of water pollution is mainly accomplished by reducing solids and organic loads to a receiving water, and by ensuring that the discharge is not acutely toxic to aquatic life. Toxicity is most commonly determined at “end-of-pipe” (i.e. without taking into consideration dilution in the immediate vicinity of the discharge). Receiving environments are biological systems with an inherent assimilative capacity for non-toxic organic material. The overall objective is to ensure that the assimilative capacity is not exceeded, and to achieve water quality that allows normal growth of native aquatic organisms, as well as human use.

Water quality standards have been set for receiving bodies of water throughout North America. In sensitive bodies of water such as inland lakes and some estuaries, nutrient removal is an issue to prevent eutrophication (excessive weed and algae growth). In the United States, total watershed management and total daily maximum contaminant loads are being implemented to identify why some bodies of water have not met water quality standards.

Industrial discharges to municipal systems are generally controlled through regulated pre-treatment programs, and punitive Discharge Bylaws, to prevent damage to the collection and treatment system, and to protect the quality of the treatment plant effluent. Charges established by Discharge Bylaws make it more cost effective for certain industries to initiate measures to reduce the contaminant loading to the sewer through source control, best management plans, and the construction and operation of onsite pre-treatment facilities.

In many jurisdictions, certification of wastewater treatment plant operators demonstrating a minimum level of technical expertise is mandatory. This certification is done at the state (US) and provincial (Canada) levels through the Association of Boards of Certification, based in Ames Iowa.

Some jurisdictions, such as the province of British Columbia, are requiring owners of new treatment works to have performance bonds, insurance, or other financial security for the government to access in the event the treatment plant does not meet its effluent discharge requirements. For example, the province of British Columbia, Canada, now requires dischargers to annually contribute to a fund for repairs, and for the eventual replacement of the entire treatment facility at the end of its life expectancy (about 30 years). State and provincial governments often also require municipalities to produce a liquid and solid waste management plan.

Cross border initiatives, such as the Great Lakes Cleanup Project, and phosphorus bans, are in place between Canada and the U.S. to protect common resources.

Institutions

Canada

In Canada, the federal departments which are most concerned with wastewater treatment and the potential impact of discharges into the environment are Environment Canada and the Department of Fisheries and Oceans Canada. The Fisheries Act in Canada is very powerful due to the general nature of its requirement that all effluent discharged into fish-bearing waters must not contain any deleterious materials. Environment Canada provides technical assistance to the Department of Fisheries and Oceans, and produces environmental standards for federal facilities such as airports, penitentiaries and First Nations reserves. Legislation which is the responsibility of Environment Canada is general in nature when applied to wastewater treatment.

Specific discharge requirements are set by provincial legislation. Each province has a provincial Ministry of the Environment, and each Territory has a Water Resource Division. These government agencies are responsible for producing environmental discharge and monitoring standards and guidelines, and for regulating and enforcing discharges. Permits are issued for each wastewater discharge. In some jurisdictions, such as British Columbia, Canada, permits will not be required in the future - rather, a minimum criteria set by regulation will have to be met.

Each province/territory also has a Ministry of Health, which regulates and monitors smaller effluent flows which are discharged into ground disposal systems. In general, individual household on-site treatment and disposal systems, and small cluster systems with flows under about 22 cubic metres per day, fall within Ministry of Health jurisdiction.

Larger service providers are mainly local municipalities and regional districts, who arrange for construction and operation of wastewater treatment plants using public funds. There are also private operations such as trailer parks, and small local treatment works for new developments. A relatively recent trend is to have operations of public treatment facilities contracted out to a private wastewater operations company. As well, some suppliers of individual package plants offer system servicing.

United States

In the United States, the Environmental Protection Agency (EPA) oversees most aspects of wastewater treatment, setting minimum specific standards which must be met throughout the country for all types of discharges, and implementing the Federal Water Pollution Control Act and the Clean Water Act. The EPA oversees the National Pollutant Discharge Elimination System (NPDES), which issues permits that are required to discharge treated wastewater to US waters. The NPDES is administered by local branches of the EPA, except where the EPA has delegated the permitting process to some individual states for management and control. State regulatory bodies may also set more stringent effluent criteria which must be met locally. For disinfection, individual states develop criteria based upon the use and quality of the receiving water body.

There are some multi-state regulatory agencies for river management still in effect which predate the EPA; for example Ohio River Valley Water Sanitation Commission (ORSANCO), formed to protect the Ohio River [http://www/orsanco.org].

In most states, the State Department of Health is responsible for regulation of on-site systems, which discharge to ground.

Service providers are mainly local municipalities, counties, and regional governments, who arrange for construction and operation of wastewater treatment plants using public funds. Lately, there has been a trend for private operations companies to offer to operate public facilities, for a savings to the administrative body. There are also private operations for small local treatment works for individual developments, trailer parks and resorts. Operation of the latter may also be contracted out to a wastewater operations company.

An interesting recent development is that private power and gas utilities in the US and Canada are becoming interested in owning and operating wastewater treatment facilities. The US based Energy and Power Research Institute is currently carrying out two initiatives in this area. The first is coordinating a US $5 million study into a number of issues surrounding decentralized (cluster) wastewater treatment systems, and the second is carrying out business plans on behalf of two member utilities for the private operation of wastewater treatment facilities in the US.

Some states are also moving towards central servicing requirements for individual treatment systems, with the objective of improving performance. Some states have implemented environmental reporting to the EPA via the Internet, as a cost and time saving measure, and to also make data more accessible to the public.

Effluent discharge criteria

Canada

BOD/TSS

In Canada, discharge criteria for federal facilities are set by Environment Canada, and all other discharge criteria are set by the provinces and territories. Most permits are determined on a case by case basis, depending on the quality and type of receiving water and the amount of discharge. Environmental impact studies are required for all federally funded and regulated discharges, and may be required by provincial authorities depending on the volume of the discharge or the sensitivity of the receiving environment.

When discharging to the ocean, until recently preliminary treatment only has been required, and is still being practiced in many coastal areas. Many plants discharging to the ocean have primary treatment only, but this is changing. For example, previously discharges greater than 0.45 ML/d to open marine outfalls required only primary treatment in the province of British Columbia, but effective July 15, 1999, a new regulation mandates secondary treatment as a minimum.

When discharging to streams and lakes or embayed marine waters higher effluent standards apply. Typically a minimum effluent quality of 45 mg/L BOD_5 and 60 mg/L TSS is required for most non-ocean discharges in Canada. Discharges to lakes and streams with low dilutions require a more stringent effluent quality. Health Regulations for small discharges to ground with poor soil conditions are often less than 10/10 (10 mg/L BOD_5 and 10 mg/L TSS) with stringent fecal coliform criteria (i.e. less than 2.2 MPN/100 mL). Similar stringent criteria apply for effluent re-use and irrigation applications.

Storm overflows in municipal areas are generally not regulated, unless they are from an industrial site.

Nutrients and toxicity

Legislation can identify environmentally sensitive zones, which require more stringent effluent quality standards. This is often based on geological characteristics such as river valley or lake systems. The Okanagan Valley in British Columbia is an example of one such zone which has stringent effluent total phosphorus and total nitrogen requirements for all municipal discharges. Effluent toxicity is also a common parameter, usually expressed as a concentration in which no more than fifty percent of the fish die over a ninety-six hours test period (96hLC50). Often the toxicity is directly related to the effluent ammonia concentration, and effluent ammonia levels are becoming more common in permit criteria for this reason. Effluent toxicity can also be due to high BOD concentrations (eg. primary effluent) which causes oxygen depletion during the test sufficient to suffocate the fish, as the test protocol allows for only marginal aeration during the test.

Disinfection

If chlorine is used, permits may specify minimum dosage, retention time and chlorine residual requirements, as well as sampling, measurement, and dechlorination requirements. Some provinces have standards for management of chlorine and sulfur dioxide containers.

In Ontario, if sufficient time downstream of a discharge is provided, disinfection may not be required. Disinfection from lagoons is generally not required unless there are sensitive downstream conditions such as a potable water intake or shellfish beds. Seasonal relaxation of disinfection requirements may be allowed if the receiving water is not used for recreational, agricultural or consumptive purposes. Most large population centres disinfect year round, but some, as in Vancouver, British Columbia, disinfect only in summer when swimming is likely.

The provinces of British Columbia, Saskatchewan, Quebec and Prince Edward Island do not favour the use of chlorine for disinfection. In British Columbia, dechlorination is mandatory, in other provinces dechlorination requirements are determined on a case by case basis. There is a growing trend across North America to disinfect wastewater effluent using ultra-violet radiation, in place of chlorination.

Biosolids

Biosolids are regulated in all provinces in Canada. Agriculture and Agri-Food Canada (AAFC), the Canadian Council of the Ministers of the Environment (CCME) and the Standards Council of Canada (SCC) (through the Bureau du Normalization du Quebec (BNQ)) are involved in development of composting standards for biosolids. In 1995, the hoped for outcomes of collaboration of the above entities were:

- a national Canadian standard for the composting industry (BNQ)
- guidelines for compost (CCME)
- the adoption of new mandatory criteria for compost (AAFC)

Voluntary standardization is coordinated by the SCC, that represents Canada within the International Standards Organization (ISO). BNQ is one of five standards writing organizations that is authorized by SCC. Among other things, BNQ has been given responsibility for soil amendments, organic fertilizers, fertilization, and treatment of municipal sewage.

CCME guidelines are being developed with four criteria for compost quality and safety: maturity, foreign matter, trace elements and pathogenic organisms. Composting is seen as an alternative for management of the organic portion of municipal waste, since Canada is aiming to divert 50 percent of the waste stream from landfills.

The Plant Products Division of AAFC administers the Fertilizers Act and Regulation, and controls compost sold as soil amendment or fertilizer. Soil amendment or fertilizer must be safe, efficacious and properly labelled, must not pose significant risk to humans, plants, animals or environment when used according to directions. Random sampling and analysis of products must meet established the criteria. The AAFC is currently (1995) working to include a direct reference to BNQ standard in the Fertilizers Regulation.

Other

Limits are often set by provincial regulatory authorities for effluent parameters which may be of concern in specific discharges. These are mainly limits upon metal levels or toxic organic contaminants in industrial or other special waste discharges.

United States

BOD/TSS

Secondary treatment is required as a minimum treatment, defined as effluent quality of 45 mg/L BOD_5 and 60 mg/L SS. Either BOD_5 or $CBOD_5$ may be the permit criteria. Receiving water quality for rivers and streams is based on a 7 day consecutive 10 year low flow regime (7Q10). Mass limits for discharges are usually set using the 7Q10, and average annual plant design flow. Discharge limits of 10 mg/L BOD_5 and 10 mg/L SS may be set in very sensitive environmental discharge conditions.

To locate remaining sources of water pollution in water bodies, where quality is low despite in place pollution controls, the EPA is moving towards total watershed management by permitting total daily maximum loads (TDMLs) in order to better control overall pollutant loadings to a watershed. Individual states identify and develop TMDLS for waters that fail to meet water quality standards despite pollution controls. Sources can trade TDML allowances.

The EPA National policy on Combined Sewer Overflow (CSO) Control was issued in 1994 and identifies 9 minimum controls to meet the technology-based requirements of the Clean Water Act. The CSO National Policy requires municipalities to develop long-term control plans and lays out targets for CSO controls to meet water quality standards and Clean Water Act requirements.

Nine minimum controls are:

1. Proper operation and regular maintenance programs for the collection system and CSOs.
2. Maximum use of the collection system for storage.
3. Review and modification of pretreatment requirements to ensure that CSO impacts are minimized.
4. Maximization of flow to the publicly owned treatment works for treatment.
5. Elimination of CSOs during dry weather.
6. Control of solid and floatable materials in CSOs.
7. Pollution prevention programs to reduce contaminants in CSOs.
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and impacts.
9. Monitoring to effectively characterize COS impacts and the efficacy of CSO controls.

The Comprehensive Environmental Response, Compensation and Liability Act (also known as the Superfund Act) covers wastewater exfiltration and overflow in the collection system, storage leaks, effluent and solids disposal, if they pose a threat to public health, welfare or environment.

Disinfection

Individual states develop site-specific water quality standards which mandate disinfection levels for municipal treatment plants. Guidance is provided by US EPA and other federal agencies, based upon 50 percent of the fecal coliform density at which a public health risk has been shown. Presently, if there is no primary contact with the receiving water, no disinfection or 800 MPN/100 mL fecal coliform is acceptable. Primary recreational contact with the water requires 200 MPN/100 mL. Reuse, irrigation and discharge to shellfish waters requires disinfection to 2.2 fecal coliforms/100 mL.

The most usual statistical basis is a minimum of 5 samples in 30 days. California has instituted a 7 day median value criteria.

Eighteen (18) states have seasonal disinfection requirements only.

Biosolids

The federal government is directly involved in the control of biosolids management practices, through municipal solid waste landfill regulations (40 CFR Part 258), technical standards for the use and disposal of biosolids (40 CFR Part 503), and expanded NPDES programs requiring federal permitting for biosolids use and disposal (40 CFR Part 122-124 and 501).

The Part 503 technical standards affect generators, processors, users and disposers of biosolids and domestic septage, and address land application, surface disposal and incineration.

Land application is defined as biosolids applied to land at agronomic rates for beneficial use. Biosolids for land application must meet Part 503's heavy metal pollutant ceiling concentration limits, Class B requirements for pathogen reduction, and vector attraction reduction requirements. General requirements and management practices apply unless the biosolids meet high quality pollutant concentration limits, Class A pathogen reduction requirements and vector attraction reduction processing requirements.

Surface disposal requirements apply to lined and unlined monofills, dedicated disposal surface application sites and piles, mounds or lagoons used for final disposal, defined as longer than 2 years. Metals concentration limits apply for unlined sites. There are management practice requirements for site location, control of runoff, methane gas monitoring, crop production, grazing and public access. States can establish site specific more stringent requirements.

Incineration requirements limit concentrations of heavy metals in biosolids fed to incinerators, and the concentration of total hydrocarbons or carbon monoxide in the exit gas from incinerator stacks. Management practices and frequency of monitoring, record keeping and reporting requirements are also established. Continuous emissions monitoring equipment, performance tests, and site-specific air modelling are required.

Facilities in states which do not have a delegated federal program must comply with both state and federal biosolids management programs.

Other

General Pretreatment Regulations in the U.S. require all publicly owned treatment works with flows greater than 19 ML/d, and smaller plants with significant industrial discharges to the collection system, to establish a local pretreatment program. Explosive, obstructive, excessively variable and excessively hot pollutants cannot be discharged to collection systems. One hundred and twenty-six (126) priority pollutants are also regulated by the General Pretreatment Regulation, and are locally enforced and implemented through the NPDES permit program. Three hundred and sixty-six (366) extremely hazardous substances have been identified, and must be traced from point of generation to disposal if municipal landfills are used for solids disposal, or if the substance does not mix with the domestic

wastewater before it enters the treatment works. State and local officials must be notified of the presence of extremely hazardous substances used as part of the wastewater treatment, i.e.: chlorine and sulfur dioxide, if in excess of specified threshold amounts.
Under the Clean Air Act, emissions of carbon monoxide, particulate, lead, nitrous oxide, ozone and sulfur oxide emissions from incinerators, dryers, engines and boilers are regulated. If pollutants defined as hazardous are emitted at greater than a threshold mass, an air discharge permit is also required.

Roles of engineering firms, contractors and public agencies

Engineering firms in North America have been instrumental in developing regulations; providing regulators with the technical background for setting effluent limits and management guidelines. This work has been undertaken both on contract and on a volunteer basis, depending upon the situation.

Public agencies such as the Natural Sciences and Engineering Research Council in Canada and the US Environmental Protection Agency (EPA), and not-for-profit organizations such as the US based Water Environment Federation Research Foundation, fund and manage research to extend the detection limits of laboratory tests, determine toxicity of given substances, and to establish treatment performance standards.

4.7 Training (Topic g)

Both universities and technical colleges offer environmental training programs. University programs include environmental engineering and environmental management degrees. University undergraduate engineering programs provide basic training in wastewater treatment concepts as part of civil engineering and environmental engineering programs. Environmental engineering programs are most commonly offered through the civil engineering department, but may also be offered through chemical engineering and bio-resource engineering departments.

Although the majority of environmental engineering programs offered in North America are graduate degrees, environmental engineering is offered at both the undergraduate and graduate level in the United States and Canada. Graduate degrees can be preceded by a related undergraduate degree (e.g. Civil or chemical), but an undergraduate degree in engineering is not required to do a graduate degree in engineering in all universities. Undergraduate engineering programs in Canada and the US are accredited by their respective national professional engineering bodies (eg. The Canadian Engineering Accreditation Board - CEAB). An advantage of the Canadian system of university accreditation is that graduates from an accredited university program in one province can register in another province without the need to write technical exams. In contrast, most US states require out-of-state applicants for registration to write exams to prove technical competency.

University training programs may also have an industry focus. For example, one environmental engineering program offered at the University of Memphis provides consulting help for small and medium sized companies trying to meet pretreatment permit requirements or NPDES permits. Graduate and undergraduate students work with a research faculty member with both industry and government experience. Students visit the site, conduct a literature review, and write a draft report. As well as recommending treatment processes, the program has provided technical assistance in negotiating with WWTP's over fees and with regulators over permit limits (Moore, 1997).

Technical college programs focus on the practical more than the theoretical aspects of environmental technology, and admission standards to these programs are not as high as those required by universities. Most of these programs are completed in two years in comparison to university engineering programs which take from four to five years to complete, depending on the university.

Wastewater operator training and certification is required in approximately fifty percent (50%) of North America. Operations training is offered through professional associations, most notably the Water Environment Federation. Universities in Massachusetts, Washington, California (Sacramento), and North Carolina have also worked with local governments to produce programs to train professionals and operators offering on-site treatment design, installation and operational services. Operator certification is governed by the Association of Boards of Certification (ABC), based in Ames Iowa, and is implemented by local state and provincial certification boards.

Continuing education for wastewater treatment professionals is encouraged, and some professional engineering associations have made proof of continuing education mandatory. Government sponsors continuing education through university programs and by workshops given at professional association conventions.

Professional associations sponsor and organize short courses and conventions, at which research and case study papers are presented and equipment suppliers provide information on new developments. Special workshops are presented on topics such as Biological Nutrient Removal, Benchmarking, and Ultraviolet Disinfection, for the purpose of educating one's peers as well as advertising one's expertise. As mentioned above, many engineering associations require that members collect a minimum number of Continuing Education Credits per year to maintain certification.

Equipment suppliers offer technology transfer workshops, which keep clients up to date on new developments as well as advertise the supplier's products. Computer models and design tools, for example, pump sizing programs, are being developed and offered by suppliers to customers.

The Internet is becoming a valuable continuing education and technology transfer tool. Professional organizations such as the Water Environment Federation, and government sponsored information centers such as the Small Flows Clearinghouse, operate discussion groups where technical questions can be asked and answered from around the continent.

4.8 Public education (Topic h)

In North America, public education regarding wastewater and stormwater treatment is handled locally. Although federal and state agencies produce educational materials, there are no set curricula in schools, or information which is required to be carried by print, radio or television media. However, the general public is fairly well informed on broad environmental and health issues due to initiatives by local governments, educators, and environmental action groups.

US government public education efforts include print materials produced by the US EPA, as well as the US EPA internet websites where materials can be ordered, and sometimes viewed.

The Small Flows Clearinghouse addresses issues specifically related to on-site and small wastewater treatment systems. As well, there are compliance centres for metal finishing, printing, agriculture, and automobile manufacturing, and is considering doing one for municipalities. Rather than physical locations, these centres are a combination of telephone hotlines, Internet sites and e-mail services operated by industry groups, states and educational organizations. They were initially financed through grants and contributions, and hope to become self-sustainable by collecting user fees or selling advertising.

A wastewater training center in El Paso, Texas run by the University of Arkansas National Water Management Center will teach US and Mexican citizens about on-site wastewater treatment and reuse of graywater as part of an effort to help farmers and rangers to manage water successfully.

There are many environmental action groups which educate the public using advertising and use of the local media to highlight areas of concern. Three of the larger and best known groups are Greenpeace, the Sierra Club, and the Sierra Legal Defense Fund.

Many of the above, as well as city centers, have developed web pages which can be accessed for information on local infrastructure. Government agencies have also published copies of legislation on the internet, available for public research. And, of course, manufacturers of wastewater treatment equipment and products advertise through web pages on the internet.

At the local level, initiatives include visits by professional engineers to schools, often organized by the local professional organization. Local regional districts often produce educational materials for use by schools, which describe the local water and wastewater treatment systems. School programs are organized by individual teachers and vary widely in the depth of information covered. In some districts on the west coast, classrooms have organized salmon enhancement programs for local small streams. Neighbourhood programs organize volunteers to paint fish beside catchbasins to remind the public that liquids discharged to the catchbasin will eventually affect the water environment.

4.9 Financing (Topic i)

4.11.2 Federal and provincial/state funding

In Canada and the United States the responsibility for provision of wastewater collection, treatment and disposal is the responsibility of local municipal and regional or county governments.

Funding for large municipal wastewater treatment projects in both Canada and the United States is typically provided by three levels of government: 1) Federal; 2) Provincial or State; and 3) municipal. The percentage contribution is often determined by the size of the project (with larger projects receiving greater levels of senior government funding), the general economic conditions at the time, and to some degree the political situation. Municipalities apply for senior government funding and then provide for the balance through municipal taxes and debt financing.

For example, in Canada, a recent federal program for infrastructure development, now completed, provided grants to successful applicant municipalities for upgrade of municipal infrastructure including wastewater treatment. A recent upgrade of a primary plant to secondary treatment in Vancouver, British Columbia, Canada worth $560 million was jointly funded from the federal infrastructure program, a provincial grant, and funds raised by municipal taxes.

Funding is also provided at times through non-municipal government agencies (e.g. US EPA, Environment Canada, and State/Provincial Environmental Departments) through technology grant programs and/or research and study grants. In the United States, the US EPA administers a Revolving Fund Loan program, and State agencies are authorized to provide loans to eligible municipalities at zero to one half of the market interest rate, such as a recent case in Massachusetts.

The 1996 EPA Needs study identified almost $140 billion dollars worth of capital projects (not including land acquisition or operations and maintenance) that would be eligible for the Revolving Fund Loan program over the next 20 years. Most of the projects are in New York, (over 11%), with Illinois and California also needing a lot of work (over 8% each). Most of the needs of smaller communities with population less than 10,000 are in the areas of secondary treatment and collection, representing almost 11% of total documented costs.
The following summarizes the breakdown of the estimated $140 billion dollars of work required (Christen, 1998):

- $44 billion for wastewater treatment
- $10.3 billion to upgrade existing collection systems (suggested low)
- $21.6 billion to construct new collection systems
- $44.7 billion to control combined sewer overflows
- $8.4 billion to control municipal stormwater and urban runoff
- $1.1 billion for groundwater, estuary and wetland protection programs.

Sources of US funding are listed in the following:

- Catalog of Federal Domestic Assistance
- Foundation Directory
- National Directory of Corporate Giving
- Corporate and Foundation Grants
- Environmental Grant-Making Foundations
- Federal Grants and Contracts Weekly.

As an example of the varied sources of funding for wastewater treatment projects in the US, a project in Suwannee Florida installed a STEP system and central treatment plant to prevent contamination of nearby oyster beds in Suwannee Sound by failing septic tank systems (high groundwater). The project was funded by the US Department of Agriculture Rural Development, the Suwannee Water District, the Florida Department of Environmental Protection, and Congress.

Other funding resources (typically for non-point sources) include (Poppe et al. 1997):

- US EPA Sec. 319 grants to states for nonpoint source projects
- US Department of Agriculture Natural Resource Conservation Service - Environmental Quality Incentives Program, and Wildlife Habitat Incentives Program
- Fish and Wildlife Foundation
- State Wallop-Breax

4.11.2 Municipal funding

In Canada, municipal funding for wastewater treatment plant capital costs and operations costs, which cannot be procured from the federal or provincial government is generated from taxes, charges to industries for discharge to the municipal system, and fees from developers for increased loading on existing plants, new collectors and interceptors.

In the United States, the above methods are also used, plus bond sales and special privilege taxes on known polluters, and user fees. An example of the latter is a tax on farmers within the Everglades Agricultural Area, to help finance the Florida Everglades Restoration program. The Florida courts have ruled that polluters should pay in proportion to the pollution they have caused, rather than spread cost over taxpayers (Christen, 1998). Some municipalities have procured used equipment for upgrades to help cut costs.

In both countries, sale of products such as repurified water and biosolids have helped to reduce operating costs.

4.11.2 Private agencies

There is a trend in the United States to privatize utilities which are providing services to citizens. The driving force behind privatization of a central wastewater treatment system is generally to generate sale proceeds which are used to upgrade facilities to bring them into environmental compliance. Other reasons have included reducing public debt, gaining expertise in operations, and resolution of local labour issues. In January of 1997, there were more than 400 municipalities in the US involved in wastewater and water privatization contracts.

About 70% of the privatization market in the US is held by Professional Services Group, Operations Management International, Wheelabrator EOS, and JMM Operational Services. Metcalf and Eddy Companies Inc. has 65 contracts (Dresse & Beecher, 1997). Historically, contracts have been mainly 3 to 5 year agreements involving operations and maintenance, but the trend is towards longer term, 25 years or so, contracts. Some municipalities have even leased facilities to private companies over the long term, but this is still rare as there is a public nervousness regarding mixing protecting public health and environment with profits.

The trend towards privatization has prompted an optimization movement (benchmarking) within the municipal wastewater workers sector, where similar facilities compare operations and costs to identify areas in which savings can be realized. In some cases, municipal workers promise to make optimization changes and save a certain amount over a period of time such as 6 years, in return for the city not bidding out operations.

Privatization of operation and maintenance contracts has also been done in Canada, for example in Banff, Alberta, although most Canadian municipalities still operate their own facilities. There is a trend, however, for facilities installed for small developments to be design/build/operate contracts, where a private utility is structured which is responsible for designing, building and operating the treatment plants..

Government regulators do not regulate what type of agency (private or public) operates the plant, as long as the operators are properly qualified (often certification is required) to operate the process and the plant meets permit requirements.

4.11 Information sources (Topic j)

Air and Waste Management Association (AWMA)

Air and Waste Management Association
One Gateway Centre, Third Floor
Pittsburgh, Pennsylvania 15222
United States

Telephone: +1-412-232-3444
toll-free 800-270-3444
Fax: +1-412-232-3450
E-mail: info@awma.org
Contact: Mike Roy
Manager of International Programs, ext. 3144

Topics covered: a, b, c, d, e, f, g, h.

Description: The Air and Waste Management Association (A&WMA) is a non-profit, technical, scientific, and educational organization with more than 16,000 members in 65 countries and chapters worldwide. The Association provides a neutral forum for addressing all viewpoints (e.g., technical, scientific, economic, social, political, and public health) of an environmental management issue. It serves its members and the public by promoting environmental responsibility and technical and managerial leadership in the areas of waste processing and control, environmental management, and air pollution. A&WMA represents many disciplines (the physical and social sciences, health, engineering, law, and management) and attracts decision makers from the government, industry, business, and research communities. It provides opportunities for technological exchange, professional development, public education, and networking.

The Association produces a variety of publications including the Journal of the Air & Waste Management Association and fact sheets on specific environmental topics. It holds an annual meeting with about 175 technical sessions, as well as periodic international special conferences and courses. The Association offers a series of teachers manuals, workshops, satellite seminars, videos, and 50-100 short continuing education courses each year. An extensive publication catalogue of more than 100 titles is available.

Format of Information: Books, articles, videos, fact sheets, special conferences, workshops, continuing education, technical sessions at annual meeting, and satellite courses.

Internet: http://www.awmag.org
Language: English and some Spanish and French.
Consulting or support services: Will refer requests to members with relevant expertise.
Fees: Fees for most meetings and publications. Fact sheets are free.

American Academy of Environmental Engineering (AAEE)

American Academy of Environmental Engineers
130 Holiday Court, Suite 100
Annapolis, MD 21401

Telephone: +1- 410-266-3311
Fax: +1- 410-266-7653
Contact: William C. Anderson, Executive Director

Topics covered: f, g.

Description: The American Academy of Environmental Engineers (AAEE) was founded in 1955, sponsored by the American Public Health Association, the American Society for Civil Engineers, American Water Works, and the Water Environment Federation. The Academy was created to implement a certification process for Environmental Engineers that embraced all areas of environmental practices such as water supply engineering, air pollution control engineering, wastewater treatment, etc. The AAEE establishes the specific environmental engineering expertise of licensed professional engineers through evaluation and examination. The Academy counsels students and perspective students who are motivated by the environmental ethic and are interested in an environmental engineering career, by providing an accurate assessment of the entry requirements and opportunities in the profession and identifying appropriate areas of study. It also works closely with government leaders regarding policies affecting environmental quality and the practices of environmental engineering.

Format of information: The Academy publishes reports, books and book store on line, articles, and a quarterly magazine.

Internet: http://www.enviro-engrs.org/
Language: English.
Consulting or Support Services: None.
Fees: Fees for certification and courses.

American National Standard Institute (ANSI)

American National Standards Institute
11 West 42nd Street
New York, NY 10036.

Telephone: +1- 212-642-4900
Fax: +1-212-398-0023
E-mail: kpeabody@ansi.org

Contact: Dr. Robert J. Hermann, Chairman

Topics covered: b, c, d, f, g.

Description: The American National Standard Institute (ANSI) is a private non-profit organization founded in 1918 and supported by divers private and public sector organizations.
The institute represents nearly 1,400 companies, organizations, government agencies, and institutional and international members. Rather than actually developing American National Standards, ANSI facilitates their development by establishing consensus among qualified groups, and enforces standard implementations. ANSI promotes the use and adoption of U.S. standards as international standards. ANSI represents the two major non-treaty international standards organizations; the International Organization for Standardization (ISO), and the International Electro-technical Commission (IEC).

Format of information: Online catalogue and reference library for standards information, quarterly reports, and special meetings.

Internet: http://www.ansi.org/
Language: English.
Consulting or Support Services: None.
Fees: Fees for most materials.

American Society of Civil Engineers (ASCE)

ASCE, Washington Office
Suite 600-1015-15th Street NW
Washington DC, 20005

Telephone: +1-703-295-6300
Fax: +1-703-295-6222
E-mail: webmaster@asce.org
Contact: Luther W. Graef, President

Topics covered: a, b, c, d, e, f, g.

Description: The American Society of Civil Engineers (ASCE), founded in 1852, is the United States' oldest national engineering society. It is an educational, technical and professional civil engineering organization, with a mission to advance professional knowledge and improve the practice of civil engineering. The Society encourages international information sharing, and has signed over 50 agreements of co-operation with similar societies in other nations. Its more than 120,000 members come from 142 nations. The ASCE works closely with government and government agencies to build and develop national policies on engineering issues. As well, it develops technical codes and standards to ensure safer buildings, water systems and other civil engineering works. Over 15 to 20 technical conferences are held annually with an average total attendance of 10,000. Continuing education seminars and computer workshops are also offered. ASCE publications include technical papers, the monthly magazine Civil Engineering, the monthly newsletter ASCE News, technical and professional journals, books, conference proceedings, manuals of practice and standards.

Format of information: Magazine, journals, publications, articles, reports, continuing education, annual conferences, and workshops.

Internet: http://www.asce.org/
Language: English.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: There is a charge for most publications, workshops, conferences etc.

Association of Consulting Engineers of Canada (ACEC)

ACEC
616-130 Albert Street
Ottawa, Ontario;
Canada K1P 5G4

Telephone: +1-613-236-0569
Fax: +1-613-236-6193
E-mail: info@acec.ca
Contact: Tim Page, President

Topics covered: a, b, c, d, e, g.

Description: The Association of Consulting Engineers of Canada (ACEC) was founded in 1925 to represent independent consulting engineers in Canada, and to promote and protect the professional interest of the Canadian consulting industry in Canada and abroad. Members include over 700 independent consulting engineering firms and 11 provincial and territorial organizations. ACEC hosts an annual conference, and publishes standard contract documents, contractual relationships, human resources training materials, and a bi-monthly magazine
(CCE Magazine). ACEC is a member of FIDIC (The International Federation of Consulting Engineers).

Format of Information: Magazine, articles, conferences, exhibitions, Internet, regular meetings, on-CD ROM information.

Internet: http://www. acec.ca/services.html
Language: English, French.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: There is a charge for most publications and conferences.

Canadian Environmental Law Association

Canadian Environmental Law Association
517 College St., Suite 401
Toronto, ON M6G 4A2

Telephone:	+1-416-960-2284
Fax:	+1-416-960-9392
E-mail:	cela@web.net
Contact:	Theresa McClenaghan, Counsel

Topics covered: f, h.

Description: The Canadian Environmental Law Association (CELA) is a non-profit, public interest organization founded in 1970 to respond to public concerns regarding complex environmental issues such as: waste generation, resource exploitation, and development effects. CELA assists governments both in drafting legislation, and at hearings. It is also willing to represent citizens or citizen groups who are unable to afford legal assistance. CELA was one of the first environmental groups in North America to address the environmental impacts of the international trade agreement. CELA shares work plans and strategies and exchanges experiences with other organizations concerned with health protection, labour, social justice, and First Nations. It participated in the activities of the following organizations, Canadian Environmental Defence Fund (CEDF), Canadian Environmental Network (CEN), Common Frontiers (links Canadian, Mexican, and American organizations on trade and environmental issues), and Ontario Environmental Network (OEN).

Format of information: Quarterly newsletter, special meetings, annual meetings, and resource library for the environment and the law.

Internet: http://www.web.net/cela
Language: English and French.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: There are charges for most meetings and publications.

Canadian Environment Industry Association (CEIA)
Association Canadienne des Industries de l'Environnement

Canadian Environment Industry Association
204-6 Antares Drive, Phase II
Neopean, Ontario K2E 8A9
Canada

Telephone:	+1-613-723-3525
Fax:	+1-613-723-0600
E-mail:	ceiaea@capitalnet.com
Contact:	G. Steve Hart

Topics covered: f.

Description: The Canadian Environment Industry Association (CEIA/ l'ACIE) is an umbrella group representing provincial companies, environmental consulting companies, laboratory services, waste management facilities, associations, and organizations that are dedicated to environmentally sustainable economic development through the provision of state-of-the-art products, technologies, and services. CEIA/ l'ACIE advocate for environmental and economic policies and regulations with provincial governments and industry associations, and promote research and training in disciplines and matters relevant to the environmental industry. The association addresses provincial environmental issues through its provincial affiliates. CEIA/l'ACIE holds conferences, produces a newsletter, and publishes conference proceedings.

Format of information: Workshops, conferences, newsletter, and proceedings are all available in print.

Internet: None.
Language: English and French.
Consulting or support services: None.
Fees: Conference and workshop proceedings are available to the public for a fee.

Canadian International Development Agency (CIDA)

CIDA
Canadian Partnerships Branch
2000 Promenade du Portage
Hull, Quebec K1A 0G4
Canada

Telephone:	+1-819-997-1167
Fax:	+1-819-994-9707
E-mail:	info@acdi-cida.gc.ca
Contact:	Linda Collette Senior Environmental Advisor

Topics covered: b, c, d, e, i.

Description: The Canadian International Development Agency (CIDA), Canadian Partnerships Branch undertakes joint development projects with industrial, non-governmental, and university partners, including technical assistance, professional services, training, funding, and monitoring and evaluation. The Partnerships Branch is involved with many projects in various countries such as Argentina, Benin, Chile, Columbia, Ecuador, Grenada, Haiti, Ivory Coast, Mexico, Panama, Peru, Senegal, South Africa, Sri Lanka, Tunisia, and Turkey.

Format of information: Information is provided through embassies or external affairs ministries.

Internet: http://www.acdi-cida.gc.ca
Language: English and French.
Consulting or support services: None.
Fees: None.

Canadian Society For Civil Engineering (CSCE)

CSCE National Headquarters
2155, Guy, Suite 840
Montreal, Quebec, H3H 2R9

Telephone: +1-514-933-2634
Fax: +1-514-933-3504
E-mail: csce@generation.net
Contact: Melu. Hasain, President

Topics covered: a, b, c, d, e, g.

Description: The Canadian Society for Civil Engineering (CSCE) was founded in 1887 to develop and maintain high standards of civil engineering practice in Canada, and to enhance the public image of the civil engineering profession. The society has local sections across Canada, providing members with opportunities for networking and professional development through regular technical programs and special technical workshops. The CSCE has an International Affairs Committee (ITA) for exchange of research and professional knowledge with civil engineering organizations in other countries. Joint cost sharing agreements with those organizations facilitate technical exchange and training. Financial assistance from the Canadian International Development Agency (CIDA) is used for activities in developing countries such as the Youth Initiative Program which gives young civil engineers the experience of living and working in the developing world.

Format of information: Journal, magazine, articles, workshops, special conferences, annual conference, national lecture tours.

Internet: http://www.csce.ca/
Language: English and French.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: Fees for most meetings and publications.

Canadian Society for Professional Engineers (CSPE)

The Canadian Society for Professional Engineers
203-College Street, Suit 303
Toronto, ON, M5T 1P9

Telephone: +1-416-598-0520
Fax: +1-416-598-3679
E-mail: akhtar@cspe.on.ca
Contact: Aziz Akhtar, President

Topics covered: f, g.

Description: The Canadian Society of Professional Engineers (CSPE) was founded in 1979 to represent and provide advocacy for professional engineers on issues affecting the regulation and practice of the engineering profession, and the rights and careers of individual engineers, in order to improve the effectiveness of professional engineers. CSPE acts as an advocacy and service organization helping to clearly define functions and responsibilities of provincial professional engineers associations. The CSPE is a member controlled service organization.

Format Information: Magazine, articles, conferences, Internet, and regular meetings.

Internet: http://www.cspe.ca
Language: English, French.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: There is a charge for most meetings and conferences.

Canadian Standard Association (CSA)

Canadian Standard Association
178 Rexdale Boulevard
Toronto, ON M9W 1R3

Telephone: +1- 416-747-4044
Fax: +1- 416-747-2475
E-mail: info@csa.ca
Contact: Standards Department

Topics covered: b, c, g.
Description: The Canadian Standards Association (CSA) is a not-for-profit organization founded in 1919 to develop standards to improve performance requirements and address quality issues, and to implement those standards through product certification. CSA tests and certifies products for both the U.S. and Canadian markets. It collaborates closely with manufacturers, industry associations, educational institutions and government bodies regarding particular safety, performance and quality issues. Services are provided to industries including Business/Management Systems, Communications/Information, Construction, Electrical and Electronics, Environment and Transportation. CSA is supported by over 8,000 members from all professions, and has a well developed local and international network.

Format of information: CSA has available over 1500 publications, and to keep its members informed about the changing standards, and requirements in the industry CSA offers seminars, workshops guidelines, handbooks, standard books and newsletters which can be provided as hard copy or on disk or CD-ROM.

Internet: http://www.csa.ca
Language: English, French.
Consulting or Support Services: None.
Fees: There is a charge for product testing, publications and conferences.

Canadian Water and Wastewater Association (CWWA)

CWWA
45 Rideau Street, Suite 402
Ottawa, ON K1N 5W8

Telephone: +1-613-241-5692
Fax: +1-613-241-5193
E-mail: admin@cwwa.ca
webmater@cwwa.ca
Contact: T. Duncan Ellison, Executive Director

Topics covered: f.

Description: The Canadian Water and Wastewater Association (CWWA) was founded in 1986 with the assistance of the Federation of Canadian Municipalities, Environment Canada and Health Canada, and the support of all Canadian water/wastewater associations. The CWWA represents the common interest of Canadian municipal water and wastewater systems, and is especially active in the development and implementation of federal and inter-provincial policies, legislation, programs, codes and standards, and certification practices. The CWWA acts as a collector, reviewer, and source of advice and information to its members. It facilitates dialogue between its members and the Canadian government, and represents Canadian interests to other national Associations.

Format of information: Videos, articles, NSPE publications, annual reports, trade shows, workshops and conferences.

Internet: http://www.cwwa.ca
Language: English.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: Fees for most publications, proceedings, meetings and conferences.

Centre for Waste Management (CWM)

University of Missouri-Columbia
Centre for Waste Management (CWM)Centre for Waste Management (CWM)Centre for Waste Management (CWM)
E2509 Engineering Building East
Columbia, Missouri 65211
United States

Telephone: +1-573-882-6269
Fax: +1-573-882-4784
E-mail: peyton@ecvax2.ecn.missouri.edu
Contact: Dr. Lee Peyton, Director

Topics covered: a, c, d, e, g.

Description: The Centre for Waste Management (CWM) is an interdisciplinary centre that promotes research and applications, technology development and transfer, and education and training in environmental and waste management. CWM focuses on waste control and treatment, waste minimization, clean production, pollution prevention, monitoring and assessment, recovery and reuse, remediation, and final disposal. Its research programs cover water quality, and water and wastewater treatment. agricultural waste, air quality, bio-remediation, fate and transport of contaminants, hazardous waste treatment, radioactive waste and waste minimization and reuse.

Format of information: Training courses, technology summary sheets, graduate-level environmental engineering courses through distant learning technology and electronic conferencing.

Internet: http://www.missouri.edu/-cwmwww
Language: English.
Consulting or support services: CWM provides consulting services in the areas described above.
Fees: Consulting services have fees. Publications are free, but there are only a few at present.

Concern, Inc.

1794 Columbia Road NW
Washington, DC 20009
United States

Telephone: +1-202-328-8160
Fax: +1-202-387-3378
E-mail: concern@igc.apc.org
Contact: Darragh Lewis (publications)

Topics covered: f, h.

Description: Concern, Inc., is a non-profit organization, which provides environmental information to individuals and groups and encourages them to act in their communities. Concern publishers and distributes reports on a broad range of issues including water resource protection, pollution prevention, recycling, and energy efficiency. It's publications give an overview of issues and include guidelines to encourage and aid citizen and group participation in the community and in policy decisions at the local, state, and federal levels of government.

Format of information: Reports.

Internet: None.
Language: English.
Consulting or support services: None.
Fees: Each publication is $4 U.S. plus international postage handling. There is an additional charge for certain large reports.

Environmental Education Enterprises, Inc.

6011 Houseman Road
Ostrander, Ohio 43061
United States

Telephone: +1- 740 368-9393
toll-free 800-792-0005
Fax: +1- 740-368-9494
E-mail: e3jklucky@aol.com
Contact: Jay Lehr, President
Topics covered: g.

Description: Environmental Education Enterprises Inc. (E^3) provides continuing education for environmental professionals on changing technology. Training seminars have a hands-on emphasis, often containing some type of classroom demonstration of applicable equipment or field training. E^3 serves engineers, geologists, and scientists working as environmental professionals, in the consulting, government, industrial and academic fields. Examples of courses are: Pollution Prevention as a Strategic Weapon; Fundamentals of Environmental Sampling; and Regulations and Environmental Technologies.

Format of information: Training programs and courses.

Internet: www. e3power.com
Language: English.
Consulting or support services: None.
Fees: Fees for courses are approximately $300 U.S.per day for standard courses and more than $1000 U.S. per day on standard computer classes where computers are supplied.

Environment Canada

Environmental Technology Centre
Environment Canada
3439 River Road South,
Gloucester, ON K1A 0H3

Telephone: +1-613-991-9550
Fax: +1-613-998-1365
E-mail: thornton.david@etc.ec.gc.ca
Contact: David Thornton, Director

Topics covered: a, b, c, d, e, f, g, h.

Description: Environment Canada is a federal government agency for environmental protection at the national level, which also maintains contacts at the provincial and local levels. The agency is concerned with setting of national standards and public education, with the current focus areas including wastewater treatment, contaminated site remediation, composting, landfill gas, construction and demolition debris, packaging recycling, life cycle analysis, and waste material exchanges. Environment Canada is composed of many specialized organizations and centres, and operates its own Environmental Technology Centre (ETC). The ETC develops and evaluates pollution measurement techniques and new technologies for municipal and industrial wastewater treatment. The ETC also advises industry, provinces, territories and the public on environmental protection technology and emerging technical issues relating to wastewater, air pollution, and hazardous materials.
Format of information: Fact sheets and reports.

Internet: http://www.doe.ca
Language: English and French.
Consulting or support services: None.
Fees: Most publications are free.

Environmental & Water Resources Institute (EWRI)

Environmental & Water Resources Institute
1801-Alexander Bell Dr. Reston,
Virginia 20191- 4400;
800/548-ASCE (2723)

Telephone: +1-703-295-6300
Fax: +1-703-295-6222
E-mail: bparsons@asci.org
Contact: Brian Parsons

Topics covered: f, h.

Description: The Environmental and Water Resources Institute (EWRI) operates under the umbrella of the American Society of Civil Engineers(ASCE) to serve and promote the needs of professionals in the environmental field, and to assist the public in protection and conservation of global resources. EWRI's members include geologists, ecologists, engineers, regulatory specialists, and politicians. Within the ASCE, EWRI takes the lead on integrating technical expertise and public policy regarding planning, design and construction of environmentally sound and sustainable infrastructure, especially relating to environmental impact. The institute provides expertise to government, industry, educational institutions and other concerned organizations and works closely with them to advance knowledge and improve practices.

Format of information: Magazine, journals, publications, articles, reports, annual conferences and workshops.
Internet: http://www.asce.org/gsd/eri/ewri.html
Language: English.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: There is a charge for most publications, workshops, conferences etc.

Fisheries and Oceans Canada

Minister, Fisheries and Oceans Canada
Parliament Buildings, Wellington Street
Ottawa, Ontario
Canada, K1A 0A6

Telephone:	+1-613-996-2358
Fax:	+1-613-952-1458
E-mail:	Min@dfo-mpo.gc.ca
Contact:	Honourable David Anderson

Topics covered: a, d, e, f, h.

Description: The Department of Fisheries and Oceans (DFO), is a federal government organization. It's responsibilities include policies and programs in support of Canada's economic, ecological and scientific interests in the ocean and freshwater fish habitat; conservation and adequate utilization of Canada's fisheries resources in marine and inland waters; and safe, effective and environmentally sound marine services. The department's mandate is to protect and manage the fisheries resources and marine and freshwater environment, and to maintain marine safety and facilitate maritime trade, commerce and ocean development. DFO is represented by its five main regions as follows:

Pacific Region: head-office in Vancouver, British Columbia
Central and Arctic region: head-office in Winnipeg, Manitoba
Laurentian Region: head-office in Quebec, Quebec
Maritime Region: head-office in Halifax, Nova Scotia
Newfoundland Region: head-office in St. John's, Newfoundland.

Format of information: Educational materials, fact sheets, monthly newsletter, annual reports, public meetings, video, radio, and TV.
Internet: http://www.ncr.dfo.ca
Language: English, French.
Consulting or support services: Will refer requests to organizations with relevant expertise.
Fees: Most publications are free.

Gale Environmental Sourcebook: A Guide to Organizations, Agencies, and Publications

Gale Research Inc.
P.O. Box 33477
Detroit, Michigan 48232-5477
United States

Telephone:	+1-313-961-2242 toll free in the U.S. only 1-800-877-4253
Fax:	+1-313-961-6083 toll free 800-414-5043
E-mail:	Beth.Demtsery@gale.com
Contact:	Beth Demtsey

Topics covered: b, c, d, e, f, g.

Description: The Gale Environmental Sourcebook contains information on environmental organizations, agencies, programs, publications, videos, and electronic products. The source book provides descriptive and contact information on approximately 12,000 resources that offer information on a variety of topics including wastewater treatment issues. Gale Research also publishes several other sourcebooks on related topics.

Format of information: In addition to print, this sourcebook is available on CD-ROM, through an online service, and on computer diskette or magnetic tape.

Internet: http://www.gale.com
Language: English.
Consulting or support services: None.
Fees: There are fees charged for all publications; the 1994 Sourcebook was $85 U.S.

Government Institutes, Inc.

A Research Place, Suite 200
Rockville, Maryland 20850
United States

Telephone:	+1-301-921-2300
Fax:	+1-301-921-0373
E-mail:	giinfo@aol.com
Contact:	Jaemi A. Noel, Manager

Topics covered: a, b, c, d, e, g.

Description: Government Institutes, Inc. publishes nearly 200 books on a variety of environmental, health and safety issues, and presents training courses and materials to professionals in those fields. Its many publications include: Pollution Prevention: Strategies and Technologies, and Federal Facility Pollution Prevention: Planning Guide and Tools for Compliance. The Government Institutes catalogue is available upon request.

Format of information: Courses, books, videos, periodicals, CD ROM products, and electronic publishing are available on a number of subjects.

Internet: None.
Language: English.
Consulting or support services: None.
Fees: Fees for all materials.

INFORM, Inc.

120 Wall Street
New York, New York 10005-4001
United States

Telephone: +1-212-361-2400
Fax: +1-212-361-2412
E-mail: inform@igc.apc.org
Contact: Bette K. Fishbei

Topics covered: h.

Description: INFORM is a non-profit environmental research and education organization that identifies and reports on practical solutions for protection of natural resources and public health. INFORM's research, reports, and communications activities focus on water conservation, chemical hazards, solid waste, and air quality and energy.

Format of information: Books, abstracts, newsletter, fact sheets, and articles.

Internet: None.
Language: English.
Consulting or support services: None.
Fees: Fact sheets and exclusive summaries of reports are free; fees for other publications vary.

International Association on Water Quality (IAWQ) Canadian Branch

IAWQ
Department de Genie Chimique
Universite du Sherbrooke
Sherbrooke, Quebec J1K 2R1
Canada

Telephone: +1-819-821-8000, ext 2165
Fax: +1-819-821-7955
E-mail: pjones@coupal.gcm.usherb.ca
Contact: Dr. J. P. Jones, Chairman

Topics covered: a, b, c, d, e, g.

Description: The International Association on Water Quality (IAWQ) is a scientific, technical and educational organization dedicated to technical and professional development, research, and technology transfer. All aspects of water quality are dealt with, including causes of water quality deterioration, control of pollution at source, improvement to existing treatment processes and development of new ones. The IAWQ has 6500 corporate members in 100 countries worldwide, including manufacturers, suppliers, consultants, institutes and government departments. The association offers an annual conference and a series of workshops and special conferences each year. Publications include Water Research, Water Science and Technology, and Water Quality International as well as conference proceedings and special scientific and technical reports.

Format of information: Journals, publications, newsletters, on-line/CD Rom products, workshops, special conferences, annual conference, and training manuals.

Internet: http://www.iawq.org.uk/
Language: English and French.
Consulting or Support Services: Will refer requests to members with relevant experience.
Fees: Fees for most meetings, conferences, and publications.

Institute of Professional Environmental Practice (IPEP)

Institute of Professional Environmental Practice
One Gateway Centre, 3rd Floor
Pittsburgh, PA, 15222

Telephone: +1-412-232-0901
Fax: +1-412-232-0181
E-mail: bcunningham@awma.org
Contact: Brenda S. Cunningham
Executive administrator

Topics Covered: g.
Description: The Institute of Professional Environmental Practice (IPEP) is an independent, not-for-profit certifying organization for the Qualified Environmental Professional (QEP) and Environmental Professional Intern (EPI) certifications. The institute was founded to improve the practice and develop and maintain high standards for environmental professionals, and to supervise the QEP and EPI examination and certification process. The institute is supported by organizations such as the Air & Waste Management Association, the American Academy of Environmental Engineers, the National

Association of Environmental Professionals, and the Water Environment Federation.

Format of information: Articles, examination and course guide.

Internet: http://www.ipep.org/
Language: English.
Consulting or Support Services: None.
Fees: Charges for EPI certifications and examinations.

Instrumentation Testing Association (ITA)

Instrumentation Testing Association
Suite 279-631 Stephanie Street
Henderson, NV, 89014, USA

Telephone:	+1-702-568-1445
Fax:	+1-702-568-1446
E-mail:	ita@instrument.org
Contact:	Carl A. Neumayer, President

Topics covered: b, c, d, e, g.

Description: The Instrumentation Testing Association (ITA) was founded in 1894 to conduct charitable, educational, and scientific testing for public safety. ITA is an international non-profit, technical and educational organization, dedicated to promoting the understanding, selection, improvement, and cost-effective use of instrumentation and automation application for monitoring and controlling water, wastewater, and industrial systems. The Association goal is to advance the practice of instrumentation and automation for water, wastewater treatment and other public works facilities by promoting the reliability and performance of instrumentation and automation technologies. To achieve this goal ITA is proactive in developing and communicating information on instrumentation and automation technologies, and providing educational programs and workshops to its members through the world. ITA's members include both manufacturers and of the instrumentation end-users such as industrial firms, public works and regulatory agencies, non-profit educational/professional scientific organizations, and academic/research institutions.

Format of information: brochures, publications, workshops, newsletters, Internet, and reports.

Internet: http://www.instrument.org/
Language: English.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: There is a charge for most publications, workshops, conferences etc.

National Association of Counties

440 First Street NW
Washington, DC 20001
United States

Telephone:	+1-202-393-6226
Fax:	+1-202-393-2630, 202-737-0470
E-mail:	friedman@spaceworks.com
Contact:	Diane Shea Associate Legislative Director

Topics covered: b, c, d, e, f.

Description: The National Association of Counties (NACo) is a non-profit association with a membership that includes about two-thirds of The United States 3,045 county governments. NACo acts as a liaison with other levels of government, acts as a national advocate for counties, and helps counties find innovative methods to meet their environmental challenges. It publishes a quarterly environmental newsletter, fact sheets on pollution prevention information sources, and a report Introduction to Sustainable Development.

Format of information: Newsletter, conference, fact sheets, report.

Internet: http://politicsusa.com/naco/
Language: English.
Consulting or support services: None.
Fees: Most publications are currently free.

National Oceanic and Atmospheric Administration (NOAA)

NOAA Office of Public and Constituent Affairs
U.S. Department of Commerce
14th Street &Constitution Ave., NW
Washington DC 20230

Telephone:	+1- 202-482-6090
Fax:	+1- 202-482-3154
E-mail:	webmaster@www.noaa.gov
Contact	Dr. D. James Baker, President

Topics covered: a, e, f, h.

Description: The National Oceanic and Atmospheric Administration (NOAA) has the role of predicting the behaviour of natural systems, protecting life and property, managing coastal and marine resources, and providing decision makers with reliable scientific information. NOAA works as an integral part of the American Department of Commerce, addressing environmental challenges and developing policies which strengthen the linkage between economic and environmental goals. NOAA works closely with other agencies of the executive branch, the legislative and judicial branches, state and local governments, academia, and the private sector to develop and implement effective resource management programs. NOAA's main sub-organizations include NOAA Fisheries, the National Environmental Satellite Data and Information Service, National Weather Service, Office of Oceanic and Atmospheric Research, and National Ocean Service. Through these sub-organizations NOAA explores future opportunities using its own conducted and directed research programs, and through networks of universities-based programs across the United States. NOAA is very active in developing and implementing various educational programs and outreach activities for primary and secondary school teachers and undergraduate, graduate, engineering and policy students. Some of its education and outreach activities include summer courses, regional and national workshops, annual conferences, and a weekly television program shown in Florida.

Format of information: On-line reference library, annual reports, articles, magazines, meetings and conferences.

Internet: http://www.noaa.gov/
Language: English .
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: Fees for most meetings, conferences and workshops.

National Sanitation Foundation (NSF)

NSF International
PO Box 130140
Ann Arbor, MI 48113-0140, USA

Telephone: +1-734-769-8010
(Toll Free (USA): 800-NSF-MARK)
Fax: +1-734-769-0109
E-mail: info@nsf.org
Contact: Tom Bruursema

Topics covered: d, f, g, h

Description: NSF International is an independent, not for profit organization founded in 1944 as the National Sanitation Foundation for the development of standards, third party product testing and certification services in the areas of public health safety and environmental protection. Technical resources at NSF include physical and performance testing facilities and analytical laboratories. NSF professionals include engineers, chemists, toxicologists, sanitarians and computer scientists with experience in public health, food safety, water quality and the environment. NSF certification programs are accredited by the American National Standards Institute (ANSI), the Dutch Council for Accreditation (RvA) and the Standards Council of Canada (SCC). NSF's principal services include: Consensus standards development and maintenance; Certification, with formally registered Marks and public Listings as evidence of compliance with voluntary consensus standards, official regulations, or product specifications; Conformity assessment and compliance monitoring; Inspections/audits, laboratory testing (physical, chemical and microbiological) and toxicological assessments related to certification; Management systems assessment and registration (ISO 9000 standards for quality, ISO 14000 standards for environment, and HACCP-9000® for food safety and quality); and related research and special studies, as well as education and training. NSF developed the NSF/ANSI Standard 40 Protocol for verifying the operating performance claimed by manufacturers for individual onsite household sewage treatment plants, and is currently working on behalf of the US EPA to coordinate the development of environmental technology verification criteria for small system wastewater treatment processes.

Format of information: Standards, listings of certified products, newsletters, seminars and workshops
Internet: http://www.nsf.org
Language: English.
Consulting or Support Services: Product testing, compliance monitoring, ISO standard assessment and registration, Centre for Public Health Education
Fees: Testing fees

National Small Flows Clearinghouse (NSFC)

Small Wastewater Flows Clearinghouse
P.O. Box 6064
NRCCE Buildings
Evansdale Dr.
Morgantown, W. Virginia
USA 26506

Telephone: +1-304-293-4191 (Toll Free USA +1-800-624-8301)
Fax: +1-304-293-3161
E-mail: nsfc_orders@estd.wvu.edu
Contact: Peter Casey

Topics covered: d, e, f, g, h, i

Description: Funded by the U.S. Environmental Protection Agency, the National Small Flows Clearinghouse (NSFC) provides technical information and information services for innovative, low-cost wastewater treatments for small communities. Small systems are defined as those with populations less than 10,000 or wastewater flows of less than one million US gallons per day, and range from septic systems to small sewage treatment plants. Emphasis is placed on finding practical, alternative solutions for "small flows" wastewater problems. NSFC provides assistance for homeowners, renters, citizens' groups, local industry leaders, research scientists, educators, local government officials, state government officials, consultants, manufacturers, operators and maintainers, contractors, and related professionals. The program addresses a range of wastewater-related topics, including: treatment technologies; design and monitoring information; financial issues; planning strategies; regulations; and education.

Format of information: Quarterly newsletters, training courses, catalogues, informational pamphlets, conferences.
Internet: http://www.nsfc.wvu.edu
Language: English.
Consulting or Support Services: Technical assistance available by telephone.
Fees: Charges for workshops and conferences, and some of written materials.

National Society of Professional Engineers (NSPE)

National Society of Professional Engineers
1420 King Street
Alexandria, VA 22314-2794

Telephone: +1-703-684-2800
Fax: +1-703-836-4875
E-mail: webmaster@nspe.org
Contact:

Topics covered: g.

Description: The National Society of Professional Engineers (NSPE) is the only U.S., engineering society that represents the United State's licensed professional engineers (PE's) across all disciplines. The Society was founded in 1934 to strengthen the engineering profession, promote engineering licensing and ethics, and to protect the rights of professional engineers (PE's) at the national and the state level. NSPE serves around 60,000 members through more than 500 chapters. The society provides a variety of services to its members including continuing education opportunities, resume placement service, employment classified, advertisements, career development, special reports, and a list of companies offering engineering and other design services.

Format of information: Videos, articles, NSPE publications, annual reports, and special meetings.

Internet: http://www.nspe.org/
Language: English.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: Fees for most meetings and materials.

Natural Science and Engineering Research Council of Canada (NSERC)

Natural Science and Engineering Research
Council of Canada (NSERC)
350 Albert Street
Ottawa, ON K1A 1H5

Telephone: +1-613-996-7235
Fax: +1-613-992-5337
E-mail: int@nserc.ca
comm@nserc.ca
Contact: Brzustowski Thomas A., President

Topics covered: a, c, d, e, g, i.

Description: The Natural Science and Engineering Research Council of Canada (NSERC) is a national organization which provides funds for research in Canada through research grants. The grants support training of scientists and engineers as well as basic university research, and research through partnerships of universities with industry. Over 3,300 Canadians hold an NSERC scholarship or fellowship, and over 8,000 Canadian researchers benefit from NSERC support. NSERC also builds partnerships between Canadian universities, governments and the private sector by funding joint research projects. NSERC offers several awards annually in recognition of exceptional contributions to research in fields supported by NSERC.

Format of information: Publications, annual reports, articles.

Internet: http://www.nserc.ca/
Language: English and French.
Consulting or Support Services: Will refer requests to members with relevant experience.
Fees: Fees for most publications.

Northwest Biosolids Management Association (NBMA)

NBMA
821 2nd Avenue MS81
Seattle, WA 98104-1598
USA

Telephone: +1-206-684-1145
Fax: 206-689-3485
E-mail: leah.taylor@metroke.gov
Contact: Leah Taylor, Manager

Topics Covered: c, d, f, g, h.

The Northwest Biosolids Management Association (NBMA) was founded in 1987 by representatives of 14 Washington State and British Columbia municipalities and sewer districts. The association members joined forces to meet the challenge of finding safe, economical ways to manage biosolids. NBMA shares knowledge about biosolids management with other member agencies, local, state, federal regulators, private organizations, and the general public, and is actively involved in promoting the beneficial use of biosolids. It's members now include over 200 biosolid producing agencies, ranging from small districts to large urban cities, and also including private agencies that manage biosolids. The association works closely with local, state and federal governments on regulations development, and the development of biosolids land application sites. The association is involved with research programs at universities and provides members NBMA members with the technical support.

Format of information: Educational materials, fact sheets, monthly newsletter, public meetings, video, annual conferences.

Internet: http://www.nwbiosolids.org/
Language: English.
Consulting or support services: Technical supports for the NBMA is provided through agreements with universities.
Fees for most Services: Fees are based on the amount of biosolids generated. The minimum is $50 U.S. and could go up to $83,000 U.S.

US Agency for International Development (AID)

Development Information Centre (PPC/CDIE/DI)
Room 105, SA18
Washington, DC 20523-1801
United States

Telephone: +1-703-875-4818
Fax: +1-703-875-5269
E-mail: pinquiries@usaid.gov

Topics covered: a, b, c, d, e.

Description: The US Agency for International Development (AID) is an independent government agency founded in 1961 to provide economic development and humanitarian assistance to overseas countries. To promote development AID works in close partnership with other U.S. government agencies, U.S. business, private voluntary organizations, and universities. AID's Information Centre is its information depository. The Centre houses a searchable computer database and other publications related to specific environmental issues such as water and air pollution, wastewater treatment, and related technologies. Staff can conduct database searches and send out annotated search reports that include relevant information such as the title, subject, author, year written, and an abstract. Full reports can then be ordered from the Information Services Clearinghouse (E-mail: docorder@disc.mhs.compuserve.com).

Format of information: Reports are available in print or on microfiche.

Internet: http://www.info.usaid.gov
Language: Primarily English and occasional French, Spanish and Arabic.
Consulting or support services: None.
Fees: Copies of reports are charged on a per page basis. Institutions in developing countries may receive up to five titles on microfiche free of charge. Ordering instructions and fees are described in an instruction sheet included with any database search.

US Environmental Protection Agency (EPA)

401 M Street SW
Washington, DC 20460
United States

Office of International Activities (OIA)

Telephone: +1-202-564-6400
Fax: +1-202-260-3923
E-mail: adrian.stephanie@epa.gov
Contact: Stephanie Adrian

INFOTERRA/USA
Telephone: +1-202-260-5917
Fax: +1-202-260-3923
E-mail: library-infoterra@epamail.epa.gov

Topics Covered: a, b, c, d, e, f, g, h, i.

Description: The US Environmental Protection Agency (EPA) was founded in 1970 to effectively co-ordinate government action to protect the environment by controlling and reducing pollution. It is the principal US federal agency dealing with environmental matters, including water, hazardous waste, air, and solid waste. Activities include: setting and enforcing environmental standards; monitoring activities related to pollution, conducting research on the causes, effects and control of environmental problems; and assisting states and local governments.

EPA's Office of International Activities (OIA) currently provides technical assistance and guidance for several projects in Asia (including China, India, Indonesia, Japan) and Latin America (including Mexico, Chile, Bolivia). It does not fund its own projects; rather, it assists projects sponsored by the US Agency for International Development or the host country.

EPA technical reports, environmental regulations, educational materials, and referrals to international environmental experts are included in INFOTERRA/USA, a part of the UN Environment Programme information exchange and referral service

Format of information: For a catalogue of publications call/write to the above given co-ordinates or use the Internet.

Internet: http://www.epa.gov
Language: English
Consulting or support services: None
Fees: A fee is charged for some publications, but most are free. Refer to the publications catalogue.

Water Environment Federation (WEF)

Water Environment Federation
601-Wythe Street
Alexandria, Varginia
22314-1994 USA

Telephone: +1-703-684-2452
Fax: +1-703-684-2492
Contact: Rhonda E. Harris, President (1998-1999)

Topics covered: a, b, c, d, e, f, g, h.

Description: The Water Environment Federation (WEF) is a non-profit technical and educational organization founded in 1928 to promote and advance the water quality industry in order to preserve and enhance the global water environment. The WEF has more than 41,000 members worldwide which include engineers, scientists, government officials, academics, educators, students, equipment manufacturers and distributors, and other environmental specialists. WEF hosts a general international conference yearly, as well as many specialty conferences less frequently. Its many publications are an important source of information for North American environmental professionals. The WEF also offers internet chat sites to promote exchange of technical information. Partnerships with other organizations include the American Academy of Environmental Engineers, American Public Works, the American Society of Civil Engineers, and the American Water Works Association.

Format of information: Magazine, journals, publications (available in Spanish, Japanese and Korean), articles, annual reports, Internet, annual conferences and workshops.
Internet: http://www.wef.org/
Language: English.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: Fees for most meetings, conferences and workshops.

Water and Wastewater Equipment Manufacturers Association Inc. (WWEMA)

Water and Wastewater Equipment Manufacturers Association, Inc.
P.O. Box 17402
Washington, D.C. 20041

Telephone: +1- 703-444-1777
Fax: +1- 703-444-1779
E-mail: wwema@erols.com
Contact: L.H. Alton, President

Topics covered: b, c, d, e, f.

Description: The Water and Wastewater Equipment Manufacturers Association (WWEMA) is a non-profit trade organization founded in 1908 to represent the interests of companies that manufacture products sold to the potable water and wastewater treatment industries.
WWEMA members are active in the development and implementation of environmental laws and regulations regarding water and wastewater treatment. WWEMA works closely with environmental protection agencies, trade and development offices, international financing institutions and other government institutions to address areas of mutual concern. It supports industry designers by providing related technical expertise.

Format of information: Newsletters, news-release, special reports, articles, annual meetings and conferences.

Internet: http://www.wwema.org/
Language: English and French.
Consulting or Support Services: Will refer requests to members with relevant expertise.
Fees: Fees for most meetings, conferences and workshops.

The World Bank

Urban Development Division
1818 H Street, NW
Washington, DC 20433
United States

Telephone: +1-202-473-1301
Fax: +1-202-522-3232
E-mail: cbartone@worldbank.org
Contact: Carl Bartone

Topics covered: a, b, c, d, e, f, g, h, i.

Description: The World Bank provides financial support and technical assistance to client governments in developing countries for municipal infrastructure and services, including wastewater treatment. Within the Bank, the Urban Development Division carries out a number of activities in the wastewater treatment area, including research and policy analysis and the provision of advice, training, and dissemination of information for bank project officers and client institutions. Through the Urban Development Division, the bank also participates in a collaborative program on wastewater treatment management involving the Urban Management Programme (UMP) of the World Bank, the Swiss Development Co-operation and the Swiss centre SKAT, and a number of other bilateral organizations. The UMP publications series contains a number of reports related to wastewater treatment technologies.

Format of information: Publications are in paper format.

Internet: http://www-esd.worldbank.org/html/esd/tsu/org/twurd/urban.htm
Language: English, Spanish
Consulting or support services: The Urban Development Division provides consulting and support services to public institutions and technical co-operation agencies.
Fees: Publications are distributed free to developing country practitioners, and at cost to industrialized country professionals.

4.11 Case studies (Topic k)

4.11.1 Reuse

Plant Name: Orange County Eastern Water Reclamation Facility
Location: Orlando, Florida
Service Population: 110,000
Flow: Design – Average 72 ML/d; Peak Hour – 144 ML/d.
Contact: Tim Madhanagopal, P.E., DEE, Plant Manager - (407) 249-6248

History

The Orange County Eastern Water Reclamation Facility is located in one of the most rapidly growing areas in the United States. This advanced water reclamation system was designed to enhance the environment of the Econlockhathee River basin in east Central Florida, reduce demand on potable groundwater by providing sufficient reclaimed water for non-potable uses, and provide sufficient wastewater treatment capacity for the East Orange County in Florida and constructed in phases since 1984. This facility allowed the decommissioning of six secondary treatment plants that had directly discharged effluent into surface water. The plant has a permitted capacity of 72 ML/d, and currently 43 ML/d of municipal wastewater. The plant was recognized for its outstanding performance by many regulatory agencies and professional organizations.

Plant Description

Raw wastewater is first screened, then enters a pista grit- grit removal system. Following grit removal is a five-stage Bardenpho nutrient removal system consisting of an in-line fermentation tank, followed by the first anoxic tank, an aeration basin, the second anoxic tank, reaeration and secondary clarification. Final ABW filters polish the effluent, which is chlorinated. Dechlorination occurs in the dechlorination zone of the wetlands, prior to reclaimed water entering wetlands vegetation zone. The treatment facility is linked with an integrated reuse system consisting of aquifer recharge, industrial reuse and wetlands enhancement. Air from the headwork's is treated for odor control in three biofilters.

Reclaimed Water Quality

The following table compares the permitted annual average values for the reclaimed water and the actual measured values for 1998:

	Permit Requirement	Actual (1998) Values
$CBOD_5$	5 mg/L	1.6 mg/L
TSS	5 mg/L	1.6 mg/L
TN	3 mg/L	2.36 mg/L
TP	1 mg/L	0.25 mg/L

The plant consistently produces reclaimed water considerably better than required by stringent regulatory permit. The reclaimed water quality is analyzed daily using 24-hour flow proportional composite sampling.

Reuse

Reclaimed water is 100% reused, thus reducing the demand on precious groundwater in the Florida aquifer. The reuse system supplies cooling water for the Orlando Utilities commission's Stanton Energy Center, a 900-megawatt power plant located adjacent to the facility. The facility now supplies this power plant with 90% of reclaimed water produced at the facility. The reuse of reclaimed water for cooling purposes was one of the first approved programs in Florida.

The water reclamation facility also reuses reclaimed water in a combination of natural and created wetlands. This was one of the first such systems permitted by the Florida Department of Environmental Protection (FDEP) under exemptions to the wetland rules. The County in cooperation with the University of Florida- Center for Wetlands conducted extensive research on the effect of reclaimed water in wetlands. This research has produced very valuable information on the use of reclaimed water in the wetlands. These wetland's provide nutrient reduction and additional cleansing of the reclaimed water. Currently, less than 10% of the reclaimed water is reused in the wetlands. In turn, the natural wetlands are enhanced to provide a valuable habitat for diverse plant and animal species.

The wetlands are sized for 23.5 ML/d. There are 60.7 ha of natural wetlands and 60.7 ha of former pine flatwoods that have been converted to wetlands. A distribution system with seven application zones delivers reclaimed water to the wetlands uniformly. A channel collects and carries the water from the natural wetlands to the created wetlands. There is an additional 66.8 ha of off-site wetlands through which effluent flows before reaching a small creek that is connected to the Econlockhatchee River. This river was designated as

Outstanding Florida Water by the State of Florida, partially due to benefits created by the water reclamation project.

There is also a 9.5 ML/d rapid infiltration basins for aquifer recharge.

In addition to the above, nearby golf courses are permitted to irrigate with the reclaimed water. Provisions for expansion include additional golf courses and green space irrigation.

Sludge Handling

Waste sludge discharged from the clarifiers is dewatered in belt filter presses to 14 to 15% solids and hauled to a nearby landfill where the sludge is landfilled with the municipal solid waste.

Financing

The wastewater customers pay a monthly fee to cover the operations cost. All developers pay an impact fee to cover the plant capacity required for their development, which finances plant expansions.

Operations, Maintenance and Management

The plant employs 30 people with annual operating costs of $5.2 million U.S. The County helps pay for certification classes, certification renewals, commercial driver's licenses, work related training and professional registration. As a result, 19 of the plant's employees are certified by the State of Florida. The County also reimburses the employees up to $1,000 per year who continue their education at local colleges and universities. Many of the staff are long term employees, with an average of 12 to 15 years' experience at this plant.

Management places a high priority on planning ahead through yearly capital improvement program based on operational and upcoming regulatory requirements.

The facility uses computers for data management, record-keeping, maintenance and personnel scheduling, purchase orders and interactive safety training. A Computer Maintenance Management System (CMMS) and a Supervisory Control and Data Acquisition (SCADA) system are being implemented in accordance with the Automation Master Plan to improve the County-wide wastewater service efficiency.

4.11.2 Oxidation ditch

Plant Name:	Streator Wastewater Treatment Facility
Location:	Streator, Illinois
Service Population:	14,800
Flow:	Design - 12.49 ML/d; peak - 40.88 ML/d.
Contact:	Greg Garbs, Project Manager. 815-672-2653

History

Streator is a former mining town, built over shallow coal mines. Industries originally discharged to the mines to prevent the mines from collapsing and because the previous wastewater plant, a secondary treatment facility built in 1955, did not have the capacity to treat all flows. In 1986, a process began to prevent dwellings and industries from discharging sewage to the old mine sites. Rainwater can still flow into the old mine sites under normal conditions.

Plant Description

The new plant, operating since late 1991, consists of a main influent pump station followed by a mechanical bar screen, a grit chamber with chain and bucket grit removal, and an orbal oxidation ditch operated in extended aeration mode. The oxidation ditch has a high buffering capacity for toxic contaminants, and features energy efficient operation. The mixed liquor from the oxidation ditch flows to two secondary clarifiers, and the clarified effluent is chlorinated then dechlorinated before discharge to the Vermilion River, which supports small-mouth bass for sport fishing.

Effluent Quality

Permit levels are as follows:

	Monthly average	**Daily maximum**
$CBOD_5$	10 mg/L	20 mg/L
SS	12 mg/L	24 mg/L
FC	400 CFU/100 ml	
pH	6 - 9	
Ammonia	April to Oct 1.5 mg/L Nov to March 4.0 mg/L	

The oxidation ditch process results in effluent with less than 1 mg/L BOD5 and TSS. The ditch eliminated the need to add tertiary filters, which saved the city more than $2.5 million U.S. in capital costs and more than $50,000 U.S. per year in operating costs.

Sludge Handling

Waste secondary sludge is thickened either by gravity, or using a mechanical gravity belt thickener. The thickened sludge is lime stabilized using a ration of 1 part lime to five parts sludge by weight. The resulting biosolids are land applied using wet hauling and subsurface injection in the spring and fall. 898 dry tonnes of sludge are handled a year.

Stormwater Management

The plant is designed for a peak flow of 40.88 ML/d, however flow from the local combined sewers has been measured at 52.23 ML/d. The majority of the combined flow is handled using two on site lagoons upstream of the main pumping station. Each lagoon has a capacity of 3.78 ML, and is fitted with subsurface coarse bubble aeration and mechanical mixers. The lagoons overflow to the old primary treatment facility. The effluent from the primary clarifiers is chlorinated, dechlorinated and discharged to the Vermilion River. BOD_5 of the effluent ranges from 20 to 100 mg/L, depending on flow. There are no permit requirements for this discharge. Sludge removed from this system is processed with the secondary plant sludge.

Flow to the plant is controlled using a vortex regulator, which does not require electrical controls or mechanical equipment. Should water levels in the collection system rise too high, even with the on site lagoons in operation, emergency combined sewer overflows discharge to the old mines. From there, the wastewater percolates through the ground into the groundwater system.

Operations

The plant employs 5 people, and had an annual operating cost in 1998 of $500,000 U.S. The plant uses an MP2 Datastream maintenance software package, Opspack for Windows, to generate and record operations and maintenance data.

4.11.3 Combined sewer overflow

Plant Name: South Commons and Uptown Park
Location: Columbus, Georgia
Flow: Two units, each 128 MGD

Problem:
Columbus's combined sewer system had sixteen overflow points into the Chattahoochee River. The State of Georgia mandated treatment of wet weather discharges into the river.

Solution:
Installation of two facilities, each consisting of six Storm King vortex separation units, for reduction of suspended solids as well as contact vessels for disinfection. Pilot studies projected annual TSS reductions of 80 percent at hydraulic loading rates of 5-7 gpm/sq. ft.

Ref: website: http://www.hil-tech.com/prdhom.html, March 16, 1999.

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5. America (Central and South)

5.0 General introduction

This regional Overview covers the countries that comprise the South and Central America Region Country names and associated populations, in the year 1995, are given in table 5.1 as follows:

Table 5.1: Countries in South and Central America Region and Populations.

Country	Population (in 1000's)		
	Total	**Urban**	**Rural**
Argentina	34,587	30,152	4,434
Bolivia	7,061	4,320	2,741
Brazil	161,790	126,190	35,594
Chile	13,951	11,823	2,128
Colombia	35,886	26,491	9,395
Costa Rica	3,330	1,441	1,859
Ecuador	11,460	6,944	4,516
El Salvador	5,310	2,685	2,625
Guatemala	10,621	4,108	6,513
Honduras	5,462	2,425	3,037
Mexico	91,606	66,396	25,210
Nicaragua	4,139	2,138	2,001
Panama	2,630	1,412	1,218
Paraguay	4,564	2,297	2,267
Peru	23,468	16,445	7,021
Suriname	410	263	147
Uruguay	3,129	2,820	309
Venezuela	21,844	18,656	3,168
Total	349,642	260.610	88.973

In general terms it may be stated that the difference between the wastewater sector in South and Central America (S&CA) and developed countries is somewhat proportional to differences observed in their economic (and perhaps, "pour cause", educational) capacities. However, digging a bit deeper, evidence would also suggest that the internal disparities and the enormous income concentrations existing in S&CA have produced a small core number of capital cities and other important cities bearing a reasonable wastewater collection infrastructure. Even so many of these cities do not possess treated wastewater outlets to the environment, or as the case may be, reasonably well operated marine outfalls.

Cities of developed countries take into consideration, for instance, the availability of infrastructure, wastewater collection facilities (and sludge hauling and soil infiltration in case of on-site options) included, as a given. The major problem in the developed world is how to optmize final destination, environmentally speaking, of wastewater and sludge. In turn, in S&CA most efforts are still concentrated, and in some cases yet to be concentrated, on the provision of wastewater collection systems. In other words, in the Region problems persist in relation to questions of public health and sanitary engineering rather than environmental engineering. The vast majority of the water utilities of S&CA are still investing and getting loans for increasing their water coverage or, at most, increasing their sewage collection rate, with likely heavy downstream environmental hazards in the future resulting from more wastewater discharged to the environment. It is fair to say that in S&CA, exceptions apart, adequate wastewater disposal still faces a significant leap from the good will and intentions and engineering plans of some to reality.

While questions relating to wastewater in S&CA are crucial, and some decision-makers and institutions are searching for tools to improve the situation, there are other factors which make the situation more complicated. Two main components include (i) plumbing facilities and (ii) stormwater collection and disposal. In the former case, a significant number of households in S&CA still do not possess an adequate bathroom, which can have a number of health and environmental implications. In the latter case, quite frequently the mere existence of drainage systems provided simultaneously with the street paving, thus being available prior to the wastewater infrastructure, can produce very negative health impacts. It will surely be used to carry clandestine sewage that can contribute to accelerated local oral-fecal transmission. Drainage has been carried by municipalities at no tariff or charge, with the negative foreseeable result, of an unmanageable sewage/storm water mixture producing enormous environmental hazards at the outlets and their surroundings.

It might also be important to establish the public health/sanitary and environment benefits associated with the list of recommended sanitation technologies. Very little has been written on the subject and many people still mix up the positive sanitary benefits of laying down sewer pipes for unserved communities and the concentrated pollution resulting from a single non-treated outlet to the receiving body. So, for non-used watertables the adoption of on-site sanitation may be stressed as not concentrating pollution though still concentrating sludge effluents for disposal. This is part of the effort required in the Region to educate decision makers and engineers.

Using developed world water and sewerage companies as a model; water and sanitation companies in the Region take their limit of work before the household as the pathway manhole. In the developed world this is quite right as it may be taken for granted that housing plumbing facilities exist and are in adequate condition. Furthermore, it is expected that housing connections are also workable. In parallel, it may also be stated that whenever septic tanks serve the developed world households it is expected that the sludge generated will be cleaned out into vacuum trucks and from them it will be pumped out into sewage treatment plants' anaerobic digesters.

In turn, let's assess what happens quite often in S&CA. In the affluent urban areas good plumbing facilities exist and the yards of households are usually adequately drained out. Septic tanks, when available, maybe well served at the household level, except for the fact that most of the times the servicing company does not provide a preventive care but attends an emergency call from the householder "because the septic tank is overflowing to the yard". This means that sludge has already left the septic tank and invaded the soakaway, clogged it and then overflown. At this point the soakaway's life span will have been dramatically reduced. Doubts still remain about the sludge disposal point, quite frequently being a close, clandestine dumpsite. When the focus is on low-income settlements the typical case is as follows: toilets and plumbing facilities are inadequate or virtually non-existent; and when existent they leak out quite a lot, thus calling for immediate public health agency action. So this is why in the non-developed world the water and sanitation companies must be completely redesigned so as to encompass a frequent house assessment, perhaps to be made by the water meter reader (monthly visits) who may also check plumbing facilities.

Last decade, in Brazil the World Bank/UNDP Low-Cost sanitation Project through its Technology Advisory Group (TAG), led by a Consultant, worked with the private sector to make the so-called low-water volume toilets (VDR) available in the market. The major impetus for the marketing of the system included the development by the State of São Paulo Technology Research Institute (IPT) of a cistern tank VDR; insertion to the toilet design code of the characteristics of a VDR (maximum 5 litres per flush); and distribution to the market by three manufacturers of around 400.000 VDRs. At the same time in Colombia Messrs. Mancesa developed the pour-flush toilet type “taza campesina”, which has served Colombia and Central American countries in various successful sanitation projects targeted at low income areas. Unfortunately given lack of Government’s support the manufacturing of VDRs in Brazil has been discontinued, a fact that may be reversed as a result of the recently-launched National Water-Saving Programme; in turn MANCESA have evolved the model for a design closer to the conventional toilet, though keeping its water-saving characteristics.

5.0.1 Health aspects

Given the above framework it is understandable that diahorrea in its various modes still afflicts S&CA. In one way or another the following transmission sources and associated diseases are noticeable, following PAHO reports:

- Oro-fecal transmission: a wide range of diahorreas, that include (i) cholera, being noteworthy the recent outbursts occurred in Peru and Brazil, (ii) salmonelosis, (iii) diahorreas caused by giardia, escherichia coli, ameba and rotaviruses.
- Caused by lack of water and poor hygiene practices: skin and eye infections, flee-transmitted typhoid fever.
- Water-related diseases such as schistosomiasis and leptospirosis, the latter always occurring after seasonal floodings in low-lying areas, examples from recent floodings occurred in Central America countries.
- Vector-transmitted diseases (vectors that either breed in water or attack near water bodies): malaria, filariosis, dengue (which has recently been recognized in almost the whole Region), leishmaniosis and yellow fever.

5.1 Wastewater characteristics (Topic a)

It is not an easy task to report what may be Regional wastewater characteristics. In developed countries, where sewage collection and treatment serve the vast majority of communities and people, it is rather trivial to identify per capita average and limits (e.g, using standard deviation) for sewage flows and analogous figures for BOD, COD, SS, N, P, etc. In contrast data normally collected in the Region quite often does not show the real situation because they reflect only what is happening in the sewered sections, which is not the prevailing situation, of all the various sewage collecting basins.

Nevertheless data collected from communities with homes and businesses utilising piped water and sewers in Central America (also valid for South America), have the following typical pollutant composition of domestic sewage:

Total Suspended Solids (TSS)	200-300 mg/L
5-day Biochemical Oxidation Demand (BOD)	200-250 mg/L
Chemical Oxidation Demand (COD)	350-450 mg/L
Total Nitrogen as N	25-60 mg/L

Total Phosphorus as P	5-10 mg/L
Oil and Grease	80-120 mg/L

In unsewered areas, but served by septic tanks, the typical pollutant composition of septage in communities of Central America (also valid for South America) is as follows:

TSS	10,000-25,000 mg/L
5-day BOD	3,000-5,000 mg/L
COD	25,000-40,000 mg/L
Total Nitrogen as N	200-700 mg/L
Total Phosphorus as P	100-300 mg/L
Oil and Grease	2500-7500 mg/L

There are many examples in the countries of the Region where areas which are reasonably sewered co-exist along side others which are poorly served and, even worse, with nearby slums and squattered areas whose people convey their sewage downstream using their own resources and means, i.e., at no help provided by the sewerage utilities. This is especially the case in the Region's largest cities where these three typical areas, namely the adequately served, the poorly served and the non-served are in most cases adjoining each other. In turn this makes things even more difficult, if not nearly impossible, for a valid assessment of overall wastewater characteristics.

In short it might be most accurately said that in the Region's wealthy areas wastewater characteristics are similar to the ones encountered in the First World cities. An exception occurs when the solid waste systems and not sewers receive food debris. In this case, which occurs quite often, sewage tends to be weaker (low organic concentration). In the low-income served areas the sewage tends to be even weaker again given the reduced food consumption.

As a general rule, which is frequently valid for the Region and non-developed countries as a whole, domestic sewage originating mostly from households, public facilities, and businesses, is still the most significant contributor to water body pollution. Even so, in some specific areas of the Region industrial wastes discharged into sewers or channels significantly worsen wastewater characteristics beyond domestic sewage contributions. This happens not only in the most industrialized cities of the Region but also in specific areas close to oil refineries, mining exploitation sites, petrochemical and industrial complexes, etc. In the Region's agriculture areas the overuse of pesticides and fertilizers have dramatically worsened the quality of wastewaters draining into downstream channels.

5.2 Collection and transfer (Topic b)

At the end of the international Drinking Water Supply and Sanitation Decade, as per data collected by PAHO, wastewater and excreta disposal facilities were extended, in one way or another, to 66% of the population of the Region. This figure represented an increase of over 7% from the 1980's coverage. The extension of urban services just kept up with the population growth, only increasing from 78 to 80%. The rural coverage increased during the same period from 22% to 32% respectively. By comparison in 1995 the total coverage increased to 69%. The urban services remained constant at 80%, while the rural services were extended to approximately 40% of the population. This information is reflected in Table 5.2.

Table 5.2: Sewage and Excreta Disposal Coverage

	Percent of Coverage/year		
Year	1980	1988	1995
Total	59	66	69
Urban	78	80	80
Rural	22	32	40

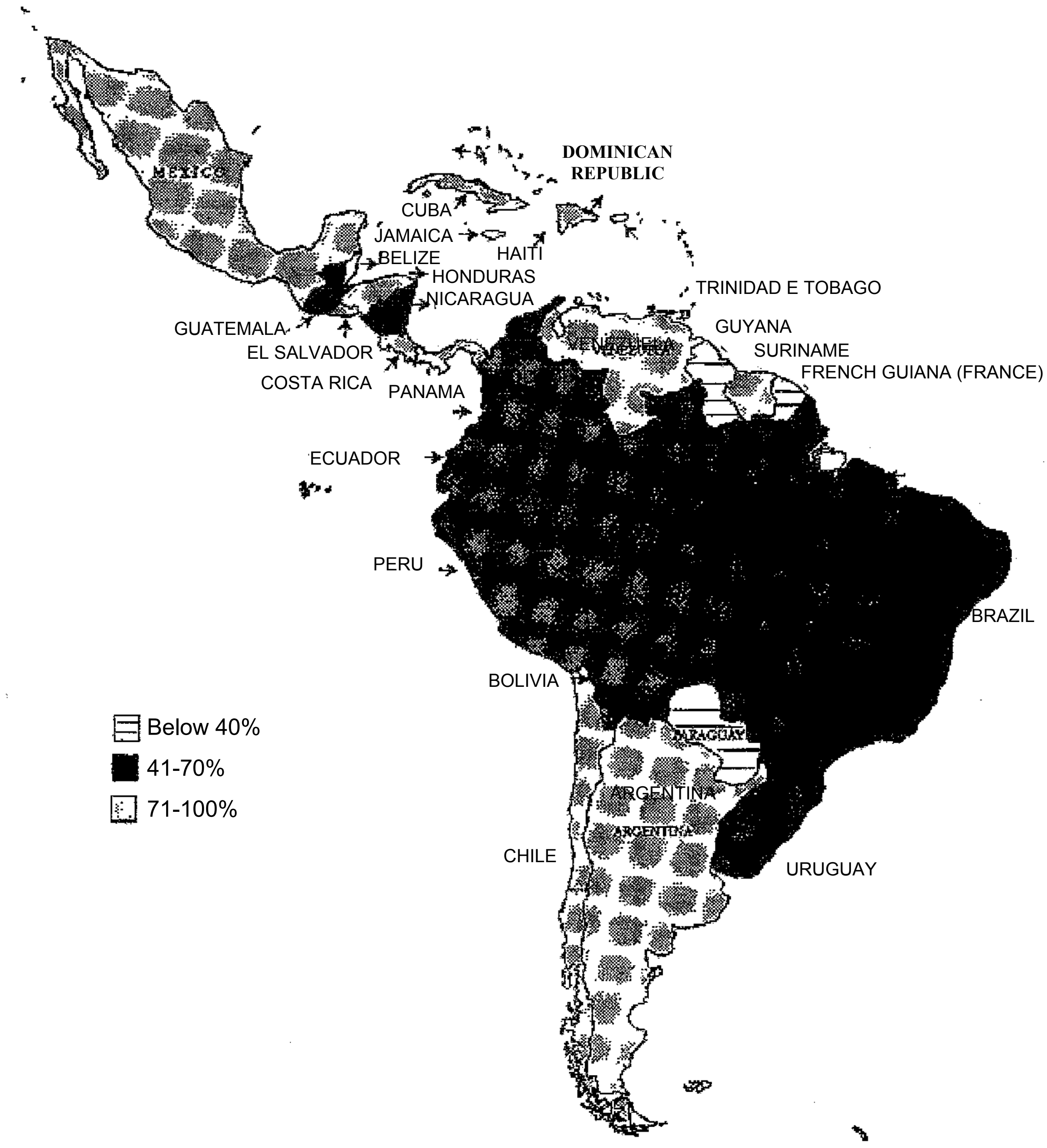
The data further indicated that in the urban areas only 52% of the population is connected to municipal sewage collection services. The remaining is served by individual systems, such as septic tanks, cesspools and pit latrines. For the most part, disposal in rural areas is handled by individual systems, mainly latrines and in limited cases septic tanks and seepage fields.

Table 5.3 and Map 5.2 show the level of coverage for sewage collection and excreta by country and for urban and rural areas; and Table 5.4 shows the comparison between the coverage in sewage and excreta disposal reported in 1995 and 1988.

Table 5.3: South and Central America population with sanitation services, data from 1995 (population in thousands)

Country	Population			Sewage and Excreta Disposal						
				Total Population Served		Urban Population				
	Total	Urban	Rural	Population	%	House Connection	%	Others	Total	%
Argentina	34,587	30,152	4,434	26,104	75	11,686	39	12,565	24,252	80
Bolivia	7,061	4,320	2,741	4,376	62	1,784	41	1,324	3,308	77
Brazil	161,790	126,190	35,594	109,075	67	44,036	35	49,563	93,599	74
Chile	13,951	11,823	2,128	11,231	81*	9,340	79	1,891	11,231	95
Colombia	35,886	26,491	9,395	21,081	59	17,219	65	1,325	18,544	70
Costa Rica	3,330	1,441	1,859	3,198	97	768	55	653	1,441	100
Ecuador	11,460	6,944	4,516	6,073	53	4,262	61	627	4,889	70
El Salvador	5,310	2,685	2,625	4,091	77	1,615	60	773	2,388	89
Guatemala	10,621	4,108	6,513	7,141	67	2,868	70	998	3,867	94
Honduras	5,462	2,425	3,037	4,453	82	1,216	50	1,078	2,294	94
Mexico	91,606	66,396	25,210	69,292	76	54,063	81	6,000	62,063	93
Nicaragua	4,139	2,138	2,001	2,437	59	730	34	1,147	1,877	88
Panama	2,630	1,412	1,218	2,381	90	899	64	500	1,399	99
Paraguay	4,564	2,297	2,267	1,465	32*	466	20	N/A	466	20
Peru	23,468	16,445	7,021	14,431	61	9,654	59	3,141	12,795	78
Suriname	410	263	147	303	74	7	2	244	251	95
Uruguay	3,129	2,820	309	1,593	61*	1,593	56	N/A	1,593	56
Venezuela	21,844	18,656	3,168	15,767	72	11,562	62	2,295	13,857	74
Total	349,642	260,61	88,973	235,2	69	120,398	52	78,124	198,051	80

- Insufficient data



Map 5.2: Sanitation Service Coverage (% of Population Served) 1995

In addition country-by country data recently issued by PAHO[1] on their 1998 Health in Americas has shown the following specific information:

- The Undersecretariat for Water Resources management have compared and analysed cities with more than 10,000 inhabitants (84% of the population). From 1991 to 1995 sewerage service coverage rose from 37.3% to 50 %, but nearly 17 million people have no sewerage connections. In the Southern Terra del Fuego sewerage coverage reached 84%

[1] Data from Brazil have come also from the Brazilian Society for Sanitary and Environmental Engineering (ABES).

of the population; and in the capital, Buenos Aires sewerage coverage rose from 46% in 1991 to 61% in 1995.

Table 5.4: Comparison between 1988 and 1995 sewage and excreta coverage

Country	1995 Coverage	1988 Coverage	Change
Argentina	75	89	-14
Bolivia	62	34	+28
Brazil	67	78	-11
Chile	81	83	-2
Colombia	59	65	-6
Costa Rica	97	97	0
Ecuador	53	56	-3
El Salvador	77	61	+16
Guatemala	67	57	+10
Honduras	82	62	+20
Mexico	76	45	+31
Nicaragua	59	19*	+40*
Panama	90	84	+6
Paraguay	32*	58	-26*
Peru	61	42*	+19*
Suriname	74	56	+18
Uruguay	51*	60	-9*
Venezuela	72	92	-20

- Insufficient data

- In Brazil the population served with sewage collection systems has risen from 28% to 30% from 1993 to 1996, the 1995 National Survey Program showing that the coverage is 71% in the urban areas against 14% in the rural areas.
- In Bolivia the sewerage connection rate rose 2.8% from 1993 to 1995. In 1996 the sewerage coverage was 44.5% in the urban areas and 17% in the rural areas.
- 84.7% of the Chilean population is serviced with sewers.
- The goal of the National Plan for Environment and Sanitation for the year 1998 was to serve 77% of the population with sewerage systems.
- In 1996 the sewerage coverage in Ecuador was 41.7%, with 61.4% being the figure for the urban populations.
- In the French Guyana sewered households jumped from 34.3% to 44.3% in the period 1982 to 1990.
- The sewerage coverage in the urban areas of Guatemala was 72% in 1994, i.e, 4.2 million people had no adequate services.
- Recent data from the Bureau of Statistics indicate that in Guyana 91.8% of the urban population and 80.4% of the rural population have access to sewage and excreta disposal services.
- In Honduras it is estimated that 82% of the population is provided with sewerage, septic tank or latrine systems.
- The mean for the percentage of sewage collected that received treatment in Mexico is 13%; Mexico has built 16 treatment systems to control the discharge of wastewater into the Lerma-Santiago River basin.
- 21.9% of the housing units were connected to sewerage systems, the Nicaraguan Water Supply and Sewerage Institute operating 19 sewerage systems.

- In Paraguay, the availability of sewerage systems nationwide in 1996 was 14.8%, being 50% the rate of the population served in Asunción, the Country's capital. In the Country's interior only two localities had such systems. There were no systems in 11 of the Country's departments, and in the remaining 6 coverage was below 10%.
- The 1995 the Peruvian Household Survey reported that 47.4% of the population had sewerage services; in the urban areas this figure was 66% and 9% in the rural areas. Latrines were used by 21.95% of the population and 24% of the rural population.
- In Suriname no buildings are required to install either sewers or septic tanks.
- Public sewerage services reach 43% of the Uruguay's population, being 51% the figure for the urban areas and 80% for Montevideo, the Country's capital. When an IDB funded project is completed the capital's figure will rise to over 95%.
- In Venezuela sewers benefit 69% of the urban population.

5.2.1 Off-site Sanitation

Conventional Sewerage

Until a couple of years ago, aspiring toward "conventional sewerage" appeared to be the only solution for the sanitation of urban areas in the Region. Even though the History of Sanitation in the Region has shown that only the main core of the most important cities has benefited from conventional sewerage. These small gains in sanitation on a Regional scale are attributed firstly to the diversion of most of the resources generated from sewerage tariffs to improve the financial situation of the existing water systems and secondly because conventional sewerage, at least under the design codes prevailing in almost all the countries of the Region, is in itself too expensive. As a result the sewerage coverage in the Region has been disastrous.

The experience in the Region to date has been to copy, without adaptation, prevailing urban patterns of American sewerage design codes. This has resulted in incredibly over designed sewerage systems with codes covering, for instance, the use of a 200 mm diameter for minimum pipe and final flow as the only design flow. This code may well be correct if we assume stable population areas, as happen to occur in the developed world cities. However, for a typical Region city whose estimated population in the next 25 years is expected to be 4 times present population the adoption of developed world codes for flow slopes relating to the final flow would possibly mean over flat slopes and oversized diameters. Aimed at solving this problem the Brazilian sewerage design code in the year 1975 introduced the ingenious self- cleansing velocity concept as follows: for initial flows the self-cleansing slope, that conducts to the self-cleansing velocity is calculated; then with this slope and the final flow, the pipe diameter is calculated. Later, early last decade Brazilian sewerage design code introduced to the Region (i) the concept already used in the developed world of minimum tractive force (ii) the use of 100mm as the minimum sewerage pipe whenever suitable for the design flow.

Solids-free Sewerage[2]

Mr. Rizo Pombo, a very competent and ingenious Colombian Sanitary Engineer developed in Colombia the so-called solids free sewerage system (ASAS). It is apparently quite similar to systems that have been used in Australia and consists of interceptors tanks used to sediment solids that are present in sewage. As the sewerage system gets sewage free of solids, it may operate under dramatically reduced slopes, which will translate to significant cost reductions in comparison to conventional sewer lines. But overall ASAS costs must include interceptor

[2] The ASAS system has been reported as "Case Study".

tanks maintenance costs (with vacuum tanks' clean out operation and further discharge to an anaerobic digester) in the comparison with conventional sewerage. Even so the bottleneck for a massive implementation of ASAS in the Region has been the mentioned bias against anything other than conventional sewerage.

Condominium Sewerage[3]

Condominium Sewerage has been by far the Region's brightest step forward towards the increase of sanitation coverage. The system was invented by Mr. José Carlos Melo, a Brazilian Sanitary Engineer, and used for the first time in 1982 in the sewerage component of the Rocas and Santos Reis Subproject held in the City of Natal, State of Rio Grande do Norte, out of the World Bank-funded Medium-Sized Cities Project. At that time the Consultant, while working for TAG, had to risk his job when he approved the condominium sewerage investment, even though it was an unapproved technology and its concepts were outside the then prevailing sewerage design codes. Presently over 4,000 km of condominium sewerage has been successfully implemented and operated in Brazil with some other countries being encouraged by the World Bank to use such technology. Moreover in the words of Mr.Carl Bartone, World Bank staff, "…the conjunction of low-water volume toilets with condominium sewerage is the most powerful tool to make adequate sanitation feasible even for the (urban) poor".

In short, condominium sewerage consists of the following aspects:

- To split a typical sanitation basin in small operational sub-basins under the concept of sewage deconcentration;
- A simplified sewerage system designed so as to minimize its length since it does not consider the property limits as a given for sewerage lay-out;
- The use of an urban block as the minimum sewage unit, i.e, the condominium, as the connected households represent a typical horizontal condominium, quite similar to what happens in terms of sewage flow in a vertical apartment building;
- The connection from the condominium outlet to a conventional public sewerage system, being current practice that the condominium outlet won't be connected to the public system unless an agreement at the block level is achieved either through connection(s) to the public sewerage system or even through individual connections, with higher prices in the latter case.

5.2.2 On-site Sanitation.

Unfortunately there is some confusion in the Region in relation to sanitation and sewerage. These words have been taken, in the practical sense as equivalent terms. As a result the many positive opportunities in the Region for sanitation companies to install on-site systems or to design for future implementation of on-site systems have not been taken, instead there is an insistance on considering conventional sewerage (off-site sanitation) as the only valid sanitation option.

As an exception to the rule, during the last decade the State of Mato Grosso do Sul Water and Sanitation Company (SANESUL), with technical assistance provided by TAG Brazil, decided to borrow money from the Federal Savings Bank (CEF)'s Water and Sanitation Fund and carry out a huge on-site sanitation programme for the low-income areas of Campo Grande, the State capital[4]. The programme comprised the supply of a sanitation superstructure including

[3] The condominium sewerage has been reported as "Case Study".
[4] Assessment of this programme has been reported as "Case Study".

cistern flush and low-water volume toilet set (VDR), shower and bathing place, and washing basin and sink. This programme has been discontinued, however there may be some chance that it will return given indications by Mr. Airton Sampaio Gomes as the President of SANESUL that it will be "resurrected", as per words by Mr. Gomes himself to the Consultant.

5.3 Treatment (Topic c)

It is estimated that nearly 100 million cubic meters of sewage is generated in the Region daily. Previous estimates for the Region, collected by PAHO for the Mid term Decade Review put the level of sewage collected that received treatment at 10% or less, but even worse, the quality of the treatment provided as generally low. Argentina is reportedly treating 10% of this sewage while Colombia reports only 5% treatment; Brazil estimates its coverage in sewage treatment at 20%.

This information is shown in Table 5.5.

Table 5.5: Proportion of urban sewage treated before discharge and associated level of treatment per country.

Country	Proportion of Urban Sewage Treated Before Discharge	Proportion of Treated Waste by Level		
		P	S	O
Argentina	10	0	100	0
Bolivia	30	33	67	-
Brazil	20	10	68	22
Colombia	5	-	100	-
Costa Rica	3	33	67	-
Ecuador	-	-	-	-
El Salvador	1	-	-	-
Guatemala	9	46	54	-
Mexico	13	14	27	59
Nicaragua	21	46	54	-
Paraguay	1	-	100	-
Peru	-	-	-	-
Suriname	1	-	100	-
Uruguay	15	50	28	22
Venezuela	-	-	-	-

* P = Primary Treatment
S = Secondary Treatment
O = Others

The water pollution problems in Latin America have been well documented and there is no evidence as far as the data show of any substantive effort to change the situation. Another aspect that must be taken into due consideration is the poor level of confidence of data collected as they appear sometimes highly contradictory even when the collecting source (PAHO) is the same.

Nevertheless some of the main efforts made in specific countries are worth mentioning. Country-by-country, some specific information may be reported as follows:

· Buenos Aires metropolitan area has constructed 20 waste treatment plants and is in the process of building 15 more, with over 80% of the sewage generated there being treated.

In Argentina as a whole it is estimated that 10% of all sewage has been treated, with 7 out of the 21 departments treating all their sewage and 2 treating nothing at all. The River Conquista Basin Project for the Greater Buenos Aires is under construction.

- In Belize, sewage treatment facilities in Belize City comprise two facultative lagoons situated south of the city. Treated effluent is discharged into canals, cut through a mangrove wetland, which discharge into the Sibun Bight. The lagoon cells operate in series and are designed to provide 10 days hydraulic retention time each, although actual retention time could be double this period in the dry season. Early problems in the lagoons included premature corrosion of chambers and weed growth. However, the lagoons are generally in good condition, providing some 80 - 85% biological oxygen demand removal. In Belmopan, the treatment involves sedimentation tanks only, with the effluent discharging into the Belize River. Not all the meters and pumps are working and the treatment plant is partly bypassed, resulting in a biological oxygen demand removal rate of about only 5%. Currently, the plant is a potential health hazard because of fecal contamination of the Belize River and, hence, the improvements should be carried out as soon as possible.
- In Brazil, of the total amount of wastewater collected, only 20% is treated or discharged to a safe marine point. Less than 30% of the sewage generated in São Paulo and Rio de Janeiro, the Country's largest cities, receive some sort of treatment before final destination. Large sewage treatment projects are under implementation such as the Guanabara Bay Depollution Project for Rio de Janeiro, and the Greater Salvador and Porto Alegre Pollution Control Project. The Tietê Project for the Greater São Paulo, the Country's largest project has been brought to a halt.
- In Bolivia sewage treatment is virtually non-existent.
- In Chile 97% of the wastewater is disposed of in waterways without prior treatment. Nonetheless there are underway the Sewage Treatment Project for the Greater Santiago (the Country çapital), and Projects for Viña del Mar-Valparaíso as well as the Lomalarga Treatment Plant.
- In Colombia, only 154 out of 1068 municipal districts treat sewage before discharging it to a water body, the amount of total treated sewage being 4.5 m^3/s. In the metropolitan areas the proportion is 12 out of 30. Enteritis, hepatitis and typhoid fevers are endemically found. There are in Colombia 202 treatment units comprising 24 percolating and trickling filters, 17 UASB's, 96 stabilization ponds, 17 activated sludge plants, 26 extended aeration plants, 6 compact plants and 16 under other processes. Regular sampling and analysis have been made only in a few selected areas, such as the Cartagena Bay. Very developed environmental legislation is available which sets standards for faecal coliforms, and wastewater effluents for new & existing plants.
- In Ecuador there are no sewage treatment systems currently available however plans for construction exist for the Cities of Quito, Guayaquil and Cuenca.
- In Costa Rica it is estimated that a mere 3% of the liquid effluents of the population are treated before reaching final destination. Limon discharges raw sewage into its harbour. No major problems exist except the high coliform count near the Limon discharge although no regular monitoring program is known to exist. Studies of coastal waters have found total coliforms (TC) to be twice that of faecal coliforms (FC). In U.S., more common values of TC:FC are 5:1.
- In Guatemala out of 27 treatment facilities there are 16 wastewater treatment plants in the metropolitan area, but only 4 of them are in full operation giving a total treated flow below 0.1 m^3/s. Only 15 municipalities out of 286 have wastewater treatment plants comprising Imhoff tanks, lagoons, trickling filters, and activated sludge. Many treatment

facilities are impaired due to poor design, lack of spares, and shortage of qualified operators.

Table 5.6: Treatment of sewage in Colombia.

	COLOMBIA			Kind of Treatment							
	Municipal Districts	Population	Municipal Districts where wastewaters are treated	Compact Plant	Trickling Filter	Stabilization Pond	Percolating Filter	UASB	Activated Sludge	Extended Aeration	Other
	30	>300,000	12	2	1	3	1	5	1	0	3
	15	>100,000 <300,000	7	0	0	4	0	0	3	1	0
	1023	< 100,000	135	4	17	89	5	12	13	25	13
Total	1068		154	6	18	96	6	17	17	26	16

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- In El Salvador, sewage treatment is poorly available, with 31 small plants under operation using various treatment systems such as tricking filters, stabilization ponds, activated sludge, Imhoff tanks, and oxidation ditches, for a total flow of 123 l/s.
- According to SANAA, the operating unit, only 11 of the 55 major sewerage systems of Honduras have wastewater treatment plants.
- In Panama 6 sewer systems serve 95% of coastal population. 4 of these systems have primary treatment (10% of coastal population); 2 systems discharge raw sewage (85% of coastal population). No information available on monitoring programs. Water quality criteria have been recently adopted based on WHO/PAHO standards.
- In Paraguay, raw sewage from Asunción, the Country's capital is discharged from 5 outfalls to the Paraguay River at a rate of 1.5 m^3/sec. Improvements in this service are to be implemented soon. In the last years the Itu and San Estanislao sewage treatment systems were remodelled.
- It is estimated that in Peru 83% of the urban sewage discharges to water bodies, whether coastal areas, rivers, lakes, or even agriculture lands with no control or treatment whatsoever. For the Greater Lima the sewage flow is around 23 m^3/s. Only 1.0 m^3/s comes from secondary treatment plants and then diverted to agriculture use. After the implementation of the Southern Lima Sewerage Project in the forthcoming years it is expected that an additional 9.6 m^3/s will be treated, so increasing the capital's sewage treatment to about 39%. As a result of the projects to be implemented in the interior of the Country in the coming years, the National coverage for sewage treatment shall increase to a figure of 40%.
- In Paramaribo, the Suriname's capital, 15% of the population still use pit latrines and 5% have no facilities at all, so that the level of sewage treatment, estimated at about 1%, is fairly within the overall low level of coverage.
- In Venezuela the percentage of treated wastes does not exceed 5%, with only 6% out of the 40 m^3/s of the sewage collected in the urban areas being treated. The majority of this treatment occurs on Margarita Island, a tourist destination. The remaining untreated flow is diverted into water bodies in and around Caracas, the Country capital, and other major cities. Isolated industrial discharges receive treatment, but residential areas are typically served by gravity sewers leading to outfalls in nearby rivers or streams. In the year 1995

there were in Venezuela 12 sewage treatment plants and 44 sewage treatment ponds serving 11 serving cities, all of them with a population less than 25,000 people with the exception of Nova Esparta, where the sewage flow is around 2,000 m^3/s. A set of new plants, including the 2,000 m^3/s extended aeration plant to be put into service in Maracaibo, for one million people are to be built. Upon completion, the new facilities will increase the population served by domestic sewage treatment in Venezuela from 3 to 25 percent. There is a significant industrial load as well as oxygen depletion and coliform contamination of rivers. Monitoring and compliance programs are being implemented. National standards for coastal water quality criteria were developed in 1983 based on EEC, WHO, and U.S. EPA guidelines.

The Consultative Meeting on Excreta and Wastewater Disposal in Latin America and the Caribbean in 1991 identified the following critical issues for the subsector which are still to be addressed seriously:

· Political support. One of the critical aspects of the problem is the low level of political support on the part of governments and relevant national sector institutions due to several factors including a lack of environmental policies. This has led to a general absence of awareness on the part of the population. With the increased resultant pollution and their effect on water quality, in particular the deterioration of water sources, the need for integrated water resources management and waste treatment and disposal will become a major issue in Latin America.

· Financing of wastewater facilities. Many problems were identified in relation to involving both the international financing agencies and the governments, including the lack of capacity of national institutions and the need to change the methodologies and criteria used for financing wastewater facilities by the international financing agencies.

· Other main issues identified were the inadequacy and/or non-existence of environmental policies and institutional deficiencies, and the need for developing and applying appropriate technological and engineering standards for waste disposal.

A new initiative to concentrate on the waste treatment needs of the Region through co-operation between the countries and the international financing agencies was recommended. This initiative emphasized the development of projects for collection and treatment of wastewater and the control of water pollution.

Greater participation of professional organizations and pressure groups was seen as an essential element to support the development of appropriate environmental policies and to address environmental issues related to waste treatment pollution. The strengthening of environmental education programs to promote community awareness and participation was also recommended to improve sector policies.

It can be mentioned, as per PAHO documents, that up to 90% of the sewage generated in the Region are discharged under no treatment whatsoever either to the environment or to 500.000 ha of agriculture lands, thus producing serious public health and environmental hazards.

The figures above show undoubtedly how serious the situation of sanitation coverage and sewage treatment is in S&CA. The conventional counter-attack measures would include a detailed survey of the needs with capital and running costs to be incurred using updated technology for collection, treatment and final disposal. Such an exercise has been made many times, though with poor results, because they fall far beyond the available resources, and almost nothing happens. As a result a surge towards concessions for (water and) sewage services to the private sector has swept the Region, along with major support being provided by multilateral agencies such as the World Bank and IDB. But even though the major problem will subsist: the public water and sewerage companies in general are running short of capital which makes it impossible for them to expand investments in sewerage and sewage treatment; and the recently privatised companies will likely have to increase tariffs so as to expand their services. Will this approach prove feasible?

5.4 Reuse (Topic d)

As reported in section 5.3 sewage treatment before discharge to the environment is more often than not defective or even non-existent which in turn poses problems for wastewater reuse in the Region. For when these wastewaters are used to help irrigate crops whose products are used for human consumption, especially fresh produce e.g, salad vegetables, the public health risk factors reach intolerable levels. In South and Central America, with important exceptions in Peru[5], Chile and Mexico, wastewater reuse is not widely spread. One one hand, this fact is undoubtedly a pity, economically speaking, but on the other hand it does not contribute to already considerable public health risk factors. Quite often wastewater reuse and treatment are measures that should be implemented simultaneously, unfortunately this is seldom the case in the Region.

The wastewater reuse in South and Central America countries is mainly designated to agricultural lands where it is estimated that about 500,000 ha of these lands have been so irrigated, some 20-25% of the overall worldwide figure.

- In the outskirts of Mexico City, the Country's capital, lands irrigated by wastewater reuse comprise nearly 90,000 ha, with a further 275,000 ha spread throughout other areas of the Country. Areas of note are (i) in the Mezquital Valley nearly 70,000 ha of agricultural lands use around 45 cubic meter per second of wastewaters generated in the Country's capital and (ii) that in the Texcoco Lake Project, in the Eastern Mexico Valley Basin 14,500 ha have been irrigated since 1971 with wastewaters that have made possible the existence of 500,00 trees and a reserve area for endogenous wild fauna;
- in Santiago, the Chilean Capital, especially in the Mapocho River Basin, around 16,000 ha are wastewater irrigated;
- in Lima, Peru, the wastewater irrigated areas account for 3,000 ha; and
- around 4,000 ha of wastewater irrigated areas exist in Argentina.

5.4.1 Mexico

In the Mezquital Valley wastewater reuse started late last century. Some 43 m^3/s of wastewaters out of 53 m^3/s generated in the Mexico City enter the Mezquital Valley. It is expected that these figures will increase by 30% as soon as the new sewerage systems are put into full operation. In this valley the wastewater storage capacity is 350 million of m^3 split into 6 reservoirs which convey into over 1,800 km of channels and canals. This system lowers the coliform figures from 10^8/100 ml to acceptable levels of 10^4/100 ml.

[5] The important example from the San Juan Ponds Project in Lima, Peru, that has been conducted by CEPIS (PAHO/WHO) is reported as a case study.

Over 70,000 ha of land was assigned to 45,000 families who grow corn and other vegetables such as oat, bean, wheat, pumpkin, tomato, etc. It is estimated that the economic value of the crops is around US$ 100 million yearly.

5.4.2 Peru

The importance of wastewater reuse is even higher in arid lands. Once again given existing poor sewage treatment the conflict between economic benefit and public health risks do appear in these areas. In the desert Peruvian coast only 700,000 ha out of 13,600,000 ha have been used for agricultural purposes, with the above mentioned 3,000 ha of wastewater irrigated land included here. If these data are compared with the population of 12,000,000 people that live in the area, the demand for a dramatic increase in the amount of wastewater irrigated area is easy to understand.

Lima, in the desert coast, is the Country's capital and largest city, with about 7.5 million people. It is undisputable that the most efficient use of the scarce water supply in Lima is a top priority as a matter of long term survival. The overexploitation of the local water tables is increasingly depleting the available water resources (the water table level has lowered around 20 meters in the last decades). While over 25 cubic meter per second of the City's raw sewage have been disposed of either to the River Rimac or straight to the Pacific Ocean. Thus a wastewater reuse policy with short term implementation measures is called for. It must also be emphasized that most of the wastewater irrigated area in Lima has been used for vegetable crops, a fact that cause diarrhoeas, intestinal fevers, hepatitis and parasitosis in their people, mostly the poor. In Lima, diarrhoea is the most common infant mortality cause and typhoid fever reaches the highest figures in the Region.

The Peruvian Agriculture Ministry has developed wastewater irrigation projects for approximately a further 10,000 ha of lands in Lima (including San Bartolo (4,300 ha), Ventanilla (550 ha) and Villa El Salvador (475 ha)), as well as in the cities of Trujillo (1,400 ha), Chiclayo (1,300 ha), Piura (1,000 ha) and Ica (450 ha).

5.5 Wastewater disposal (Topic e)

The unmet needs of wastewater and excreta disposal in Latin America and the Caribbean were estimated in 1988 at 162 million people lacking adequate means of disposal, 73 million in the urban areas and 89 million in rural areas. By the end of 1995 and based on figures provided by those countries, the total unmet needs were 145 million, 67 million in urban areas and 78 million in rural areas. Data for the end of the 1990's ("the lost Decade") is still being collected but given the economic crisis that has swept the Region it is likely that the demand figures have increased once again.

For the most part, the lack of infrastructure for water supply and sanitation services was blamed for the resurgence of cholera in Latin America. One of the most critical sanitary problems in Latin America remains the lack of sewage treatment and/or adequate disposal sites. Untreated (raw) and inadequately treated sewage have contaminated surface and groundwater. The contamination of groundwater by nitrate from raw sewage has caused a large number of water producing wells to be abandoned. The situation is no better even for cities that possess final disposal outlets because lack of maintenance has put most of the systems in environmental jeopardy.

Table 5.7: Compiles existing data on waste discharges regarding the receiving water body.

Country	Proportion of Waste Discharge in Rivers, Lakes and Sea		
	R	L	S
Argentina	-	-	-
Bolivia	8-	20	-
Brazil	-	-	-
Colombia	-	-	-
Costa Rica	98	-	2-
Ecuador	80	1	-
El Salvador	-	-	-
Guatemala	-	-	60
Mexico	-	-	1
Nicaragua	19	80	-
Paraguay	100	-	-
Peru	-	-	-
Suriname	-	-	-
Uruguay	90	8	2
Venezuela	66	24	10
Argentina	-	-	-

** R = River L = Lake S =Sea

The effectiveness of existing disposal facilities in the Region is usually constrained by limited capacity, poor maintenance, process malfunction, poor maintenance practices, and lack of experienced or properly trained staff. Most collection and treatment facilities dispose of their effluent and wastes directly into the closest receiving water body, which soon exhibits high coliform concentrations and low dissolved oxygen levels.

In rural areas of the Region, collection systems are rarely used, and pit privies and latrines are the most common waste disposal systems. These processes can be most effective, provided they are designed, installed, maintained, and used properly. The biggest problem with them, nevertheless, is lack of maintenance. Pit latrines, and pit privies need to be desludged periodically. Failure to desludge has resulted in contamination of the environment.
In areas of higher population density, it is feasible to develop a local collection system and use a single facility to treat the community's wastes. Lagoons, stabilisation ponds, and aerobic package plants are common and useful treatment options for medium-sized communities in the Region, except that effluent control practices are weak and therefore a lot of these units have been reported to be operated poorly.

In centralised, urban centres, lagoons, package plants, and conventional activated sludge systems are used. Many of these treatment facilities do not provide adequate treatment because of improper maintenance, and lack of skilled operators. Similar problems happen with the operation of marine outfalls.

General problems that affect sewage disposal in the Region may be summarized as follows:

· Lack of knowledge by the people, especially the poor, of the existence of a clear link between foul waste disposal and public health diseases. Environmental and sanitary education are topics still to be conveyed to people, yet are required for further practical actions to be taken by a large portion of the Regional population. People from low-income areas quite often do not rank as a priority of Governments for the implementation of adequate waste disposal facilities in their communities and usually do not demand their Governments to change their ranking.

· Culturally speaking there is "common understanding" in the Region that as wastewater facilities are not part of the ordinary infrastructure package, when they exist they may be offered free of tariffs.

· Weak political backing by governments, relevant sectoral agencies and even NGO's towards the enforcement of environmental policies to guide sewage disposal and the implementation of adequate sewage disposal services.

· Financing of wastewater facilities has been neglected by sectoral agencies and even by multilateral agencies which have used money allocated to wastewater works to cover inefficiencies of the water sector.

· The lack of dissemination of alternative, lower cost measures/facilities that might contribute to improve the economic/financial feasibility of waste disposal systems.

A lot of projects handling wastewater disposal from medium and large sized areas have been poorly designed mainly because there is a poor understanding of what measures need to be taken to protect the environmental values of receiving waters. Generally speaking, very little in the Region, to say the least, has been discussed regarding the adequate sewage treatment and disposal option that may restore environmental conditions now damaged by foul waste disposal. Activated sludge (and other BOD reduction alternatives) has been considered to be the default option even for coastal areas where, for instance, the post-treatment/disposal bathing conditions must be the environmental indicators.

5.6 Policy and institutional framework (Topic f)

The Regional has been experimenting with a dramatic institutional change as a matter of survival. As a rule in the Region, water supply and sewerage services have been provided by a broad range of public agencies operating at national, state, municipal and local levels. The various functions such as planning, financing, operation and maintenance have been spread through several ministries and agencies. A number of constraints to sector development have been identified in the PAHO survey for the 1995 sector review. The five most serious constraints identified by the countries in order of priority were:

· the lack of government policy for the sector;
· the limitation in funding (see 9 – Topic j);
· the inappropriateness of the institutional framework;
· the inadequacy of the cost recovery systems;
· and the obsolescence of existing legislation.

In addition it may also be stated that an inherent lack of priority, overlapping responsibilities and duties, poor enforcement of law and regulations and lack of reliable data bases over the last decade have contributed to the present weak situation in the Region. This is more vividly shown when compared with Region's overall development in the same period. Other constraints were the lack of trained professionals and technicians, logistics, the poor involvement of communities, lack of knowledge of water resources, and lack of appropriate technologies.

To help explain the present situation and present reasons for failures the following arguments appear to be valid. Some of the comments were provided by Mr. Sergio Mendonça, PAHO Sanitary Engineer, based in Colombia:

· There is too high a cost associated with conventional technologies. Large and complex facilities are inconsistent with available social and economic works which indicate that no more that 5% of family's monthly income should be allocated to pay for water bills. Doubling at least that figure so as to consider sewerage bills, it becomes obvious why poor people are unwilling to pay for sewerage and sewage treatment costs. For the poor people a US$ 120 family monthly wage in the Region is usual and the US$ 6 to pay for the sewerage and sewage treatment cannot be recovered even using a strong cross-subsidy approach, which makes the search and use of cheaper sanitation technologies mandatory.

· Water supply has still been regarded by politicians as of higher priority before sewerage and sanitation, even when faced with environmental hazards resulting from foul final disposal. Diversion of sanitation resources, for instance resulting from sewerage tariffs, to the water sector is common even though efforts are usually far from benefiting the target population.

· Water which is unaccounted for, and water losses, as high as over 50% and 30% respectively, also pose extra burdens on the water services. It is an important reminder that water in excess also increases the wastewater volumes.

· Defective sanitation services management. There has been too large a proportion of money and resources placed into institutional systems when compared to operational activities.

· Wastewater companies have disregarded on-site sanitation as an adequate and permanent solution for certain areas in favour of complete and new off-site systems for any given area. Sanitation companies in the Region are self-proclaimed "sewerage" companies. This can be called the "all or nothing at all" approach.

· The historic and current adoption of the plot's frontline the limit for the care taken by the sewerage companies not only is a public health big mistake but also precludes the use of the householder's yard as a sewer way, thus undoubtedly making investment costs more expensive – longer sewers which on top of that quite frequently demand disruption and reconstruction of paved pathways and streets so as to accommodate the public system.

· Minor exceptions apart, water and sewerage companies have been unable to get community support for the works and thus have received contributions toward cost reductions.

In addition, it should also be stressed that the Region has an ever-increasing urban population, which creates a further problem in that the sanitation systems never get completed as they must be always under extension works with the designer never knowing whether to adopt conservative and currently cheaper “design” population or, in turn, higher (and costlier) figures so as to accommodate future flows.

It is also important to mention the Region’s lack of understanding of the mutual implications of sanitation and drainage with other urban services and their mutual implications in public health/sanitary and environment aspects. Also as pointed out by the late Ned Echeverria, urban professional and WB staff up until his retirement in the last decade, the overall "urban pattern" of a given area in one way or another shall determine the level of service for a projected component. In other words, the sanitary engineer’s preliminary decision of laying down the "best" solution may be discarded in favor of another one which aside from providing the same health benefits to the community will be both closer, in terms of "user comfort", to other available services and, moreover, cheaper.

Most of the shapes of the urbanizations of slum areas and organized settlements and even important parts of cities do not match the requirements for conventional sewers to be laid down. It is not unusual in these areas to see streets which are narrow enough to accept truck traffic, but design codes for pipe excavation, manhole construction and cover expect to install sewers in heavy truck streets, which convey to wastage of resources or even worse with the solemn declaration that the project area is improper to get the (conventional) sewerage benefit.

It is the common practice from the sewerage master plans in the Region to increasing the sewage concentration with economies of scale as the big justification. This strategy only really helps the designers and big contractors as changing various small and easy-to-control systems into huge and industrial structures, including also huge trunk sewers and pumping stations that require a level of skill for their operation and maintenance, make them suitable only for big companies. In addition the larger the system, larger will be the risks of a foul spill to the environment.

5.6.1 Regulatory framework

The water and sanitation sector is a typical example of a natural monopoly which results in justifiable and perhaps inevitable intervention from the Public Power at least to determine and establish the rules for the work otherwise leaving space for overpriced tariffs, low competition and/or provision of deficient services to the users.

The question that has swept the Region over the present decade regarding the water and sanitation institutional framework is whether to adopt a new model which would include the participation of the private sector in the hope of bringing more efficiency and new sources of funding, entrepreneurs and operators to the Sector, with strategic decisions still being taken by the Public Power.

Chile and Argentina have pioneered the insertion of the private companies in the sanitation sector, although it must be noted that in Chile the regulatory processes were established by the Government before privatisation started, and in Argentina both actions were initiated almost simultaneously.

Chile

The Sanitary Services Office (SSS) was created in 1989 as a result of the lessons learnt from the privatisation processes which occurred in the early 80’s in the energy and telecommunications sectors. It is a relatively small, autonomous and decentralised agency, comprising about 100 employees, administratively linked to the Public Works Ministry, with its general Director being chosen by the country's President. Its operational costs are born by the country's annual budget. SSS's responsibilities include the awarding of water and sewerage concessions to private contractors, the establishment of criteria for the provision and implementation control of (i) tariff schemes and (ii) service quality codes and standards.

As the Chilean experience has been considered to be the most successful to the sector at the Regional level it has been found useful to summarize SSS's main regulatory characteristics as follows:

- a clear institutional partition between regulation and operation activities;
- the implementation of a tariff structure easily understood by the users, that is based upon efficiency criteria that are revised every five years;
- the use of a coherent cross-subsidy policy that benefit low-income users;
- the adoption of a long-term profit system under given internal rates of return.

Argentina

The sectoral regulatory framework established for Buenos Aires, Argentina, was created in April, 1993; it describes the basic parameters to guide the services to be provided by Aguas Argentinas (the concessionaire) and the duties of both the Government and the users. The regulatory entity, Ente Tripartito de Obras y Servicios Sanitarios (ETOSS) is an autonomous agency whose main responsibilities are to assess the concessionary performance before its contract obligations, including the approval of expansion and maintenance programmes.

ETOSS's Board comprises six persons, two for the Federal Government, two for the Buenos Aires City Hall and two for the Buenos Aires Province. About 110 professionals whether staff or consultants work for ETOSS, whose expenditures are covered by a charge of 2.67% over the water and sewerage tariffs issued. This agency is divided into six sections, a fact that has been blamed on a somewhat low-speed response to decisions. Some sort of administrative merge is under discussion to solve the problem. There is also an ongoing debate between ETOSS and the concessionaire regarding contracts and norms, with the former stressing that as a representative of the asset's owner – the Government – the goals must be achieved under adequate procedures, e.g, including environment protection and high quality standards, and the latter pinpointing only the needs for the achievement of the goals. The background issue is the level of freedom to leave up to the concessionaire the achievement of the goals under an optimised investment strategy without posing threats to the public health.

5.6.2 Institutional arrangement

From the end of the last decade, Regional countries have been engaged in a process of sector reform. Tremendously pressed, it is fair to say, by multilateral and bilateral agencies, especially The World Bank and IDB. In turn some Region's Ministries of Health still keep using as much as possible the WHO water and sanitation model especially for rural areas and small urban communities. Whereby the major targets are not the utilities' economic/financial positive situation but the support to users even under major subsidies. Quite often these two policies are applied simultaneously in the same country which makes the sector working in a very peculiar situation, nevertheless with an expected likelihood of prevalence in the future of the multilateral banks' arrangement.

These reforms were prompted by the lack of efficiency of the agencies in the sector. In fact, water and sewerage agencies have been highly subsidized by the central and local governments and served as a place of employment. One important aspect of this modernisation of the sector has been a move towards decentralisation, municipalisation and towards increased participation of the private sector in the water sector through various reforms. The World Bank, for instance, haven't agreed to fund the Nicaragua Water and Sewerage Project unless the Country's sectoral system was transferred to the private sector through a management contract; an analogous procedure has been taken before SANAA, in Honduras.

The largest sanitation coverage by private organizations has been reported by Argentina, with an estimated 9.5 million people served by five agencies. Other countries like Bahamas, Brazil, Chile, Honduras, Peru, have also reported limited institutional shifts towards private entities. In Chile, the Regional Water and Sanitation Companies have decentralized and are operating on a commercial basis; In Brazil, companies previously established in the States under the National Sanitation Plan have initiated management contract schemes following the Central Government policy; in Colombia, greater responsibility has been given to the municipalities for the development of infrastructure services, including drinking water and sanitation.

Some of the following cases of sectoral privatisation in the Region are important because they tend to establish in one way or another the new working model promoted by the multilateral agencies.

Buenos Aires, Argentina

The services provided by Obras Sanitarias de la Nación (OSN) were far below adequate standards, bearing all the problems used to characterize the government as a fragile entrepreneur, such as operational weakness, defective administrative and financial management, virtually nonexistent systems maintenance and too much political interference. In 1993 an international competitive bidding was run by the Government with the World Bank's support whereby a 30 year management contract was awarded to Aguas Argentinas (see above), a private consortium established by French, British and Spanish water companies as well as two Argentinian financial corporations.

In 1994 IFC an affiliated organization to the World Bank took 5% of the new company's shares as a matter of demonstrating the Bank's interest in the process. The contract describes the new company's targets in physical terms as a 100% water coverage and 95% sewerage coverage before its expiration, against present and respective figures of 70% and 58%. Nearly US$ 4 billion is expected to be invested by the new company to meet the established coverage figures. Personnel and all OSN's physical assets have been transferred to the new company. By the end of the contract's expiration the latter have to return to the Government in adequate working conditions.

It must also be stated that other major Argentinian provinces such as Corrientes, Santa Fé, Formosa and Tucumán have also undergone similar privatization processes.

Cartagena, Colombia

By the year 1995 the water and sewerage coverage in Cartagena, Colombia was respectively only 70% and 58%. The Empresas Públicas Distritales (EPD) used to give the people a very inadequate set of services. Various Governments submitted EPD to restructuring processes, nonetheless with poor results, so that in 1993 the City's Mayor decided to shut it down and asked the World Bank support for the establishment of the new company. The bidding process was won by Aguas de Barcelona, a Spanish group, and after a set of negotiations 50% of the new company's shares became divided among Aguas de Barcelona itself and some private investors, with the Cartagena Town Hall bearing the remaining 50% for the 26 years of the management contract. It is expected that the investments made by the new company will maintain the same high level achieved in the first years of the management contract.

Rio de Janeiro, Brazil

Financial and institutional questions appear to play an important role in the water and sewerage sector, especially in the coastal and tourist areas of the City of Rio de Janeiro. The State Water Company (CEDAE) has reached its threshold of investment capacity, with present deficiencies in the maintenance and care of its systems, facts that are unlikely to reverse in the foreseeable future. Even without writing the rules for a new management model it is quite clear that the State Government has decided to split CEDAE to pieces and leaving parts of the company to the Rio City Hall and to private companies, the latter under management contracts.

Given the demonstrative capacity of the cities covered in these examples (Santiago, the Chilean capital, might also have been described for its importance) it would seem the privatization trend in the Region is a given for the future, especially for the large and even some medium-sized cities. It is hoped cross subsidies may make systems feasible even for low-income people by improving attractiveness of delivery for the private sector. Nevertheless, there are still areas of concern regarding the less wealthy areas that suffer the same problems depicted above for publicly-run water companies; where for example sewerage tariffs have been diverted to the water systems so as to hide the presence of inefficiencies causing major long term problems.

5.6.3 Policy Framework

There are no doubts that the sectoral policy trends are towards some sort of private insertion to the provision of services, with the likely prevalence of the concession arrangement over a "pure" private scheme such as the British one. So, within this framework the major question relates to the level of independence of the regulatory agencies which will allow the agency and service providers the maximum level of performance. The relative weakness of Regional Governments tend to convey them to the adoption of some sort of Government-controlled agency instead of giving agencies the freedom to establish policies and assess performance level indicators/parameters, thus avoiding the existence of a Government inside the Government. On the other hand it is clear that, especially in poor countries, the risk of manipulation in terms of loosened measures and low-competitive practices as a result of pressure made by private entrepreneurs is not low, so that the "one country, one model" scheme perhaps will come true in the Region. In Buenos Aires, for instance, there are some complaints that the vast majority of services hired by the concessionaire come either from their stockholders or from subsidiairy companies of one of the owners. But in one way or another the private sector will take the major role as a matter of sectoral policy for the future, leaving it up to WHO to approach part of the outskirts of the urban centers and the rural areas and to NGO's some small share of the demand.

5.7 Training (Topic g)

The notes below are mostly based on the Latin America and the Caribbean Sanitary and Environmental Engineering Teaching Institutions Directory, that was published in 1991 by the WHO/PAHO's Health and Environment Programme (HPE). It must be stressed that the first version of this publication, released in 1987, concentrated on sanitary and public health engineering. The second version released in 1991 reflected the worldwide trend toward environmental considerations that had swept the Region's countries[6] by expanding the scope of existing courses towards environmental engineering or creating new and pure environmental engineering courses.

The professional training scope in the Region has widened over the 90's for better or worse from the anthropocentric sanitary engineering to the ecocentric environmental engineering. It is also worthwhile mentioning that PAHO is updating the aforesaid document which will be issued later this year. Predictions for this updated document are for an even greater emphasis on environmental engineering.

Table 5.8: Institutions that offer graduation and post-graduation courses in sanitary and environmental engineering:

Country	Graduation Courses	Post-Graduation Courses
Argentina		1
Brazil	7	10
Colombia	5	4
Chile	1	2
Ecuador		1
Guatemala		1
Mexico	3	7
Panama	1	
Peru	2	1
Venezuela	3	2

[6] Though referred to in the title no specific course was reported as existing in the Caribbean countries.

5.7.1 Existing graduation courses

Table 5.9: Existing graduation courses in Brazil

Institution	Course	Address	Telephone	Title Issued
Federal University of Mato Grosso, Sanitary Engineering Department (ESA)	Sanitary Engineering	CCET Cidade Universitária Cuiabá MT PO Box 78000	(55 68) 315-8720	Sanitary Engineer
Mauá Technology Institute Mauá Engineering School (FEM)	Sanitary Engineering	Estrada das Lágrimas 2035 São Caetano do Sul SP, CEP 09580	(55 11) 442-1900	Sanitary Engineer
Campinas Catholic University Technological Sciences School (FCT)	Sanitary Engineering	Rodovia D. Pedro I, km 112 Campinas SP, CEP 13100, PO Box 317	(55 19) 252-0899	Civil Engineer, specialized in Sanitary Engineering
Campinas State University (UNICAMP) , Technological Education Superior Center (CESET)	Water and Sanitation Technology	Cidade Universitária Zeferino Vaz Campinas SP CEP 13100, PO Box 1170	(55 19) 239 1301	Water and Sanitation Technician
State of Bahia Federal University, (UFBA), Polytechnical School (EPUFBA)	Sanitary Engineering	Rua Augusto Viann s/n Salvador, Bahia, CEP 40000	(55 71) 245-2811	Sanitary Engineer
State of Para Federal University (UFPa) Technological Center (TE)	Sanitary Engineering	Campus Universitário do Guamá Belém Pa CEP 66000, PO Box 549	(55 91) 229-2088	Sanitary Engineer
State of Santa Catarina Federal University (UFSc) Sanitary Engineering Department (ENS)	Sanitary Engineering	Campus Universitário de Trindade Florianópolis SC CEP 88049, PO Box 476	(55 42) 248-2480	Sanitary Engineer

Table 5.10: Existing graduation courses in Colombia

Institution	Course	Address	Telephone	Title Issued
Corporación Universitaria de Boyacá (CUB), Sanitary and Environmental Engineering School (FISA)	Sanitary and Environmental Engineering	Calle no. 19, no.11-64 Tunja Boyacá PO Box 1118	425-930	Sanitary Engineer
Antioquia University	Sanitary Engineering	Calle no. 67, no. 53-108 Ciudad Universitaria, Medellín Zona Postal 1, PO Box 1223	263-0011	Sanitary Engineer
De la Salle University (US), Sanitary Engineering School (FIS)	Sanitary Engineering	Carrera no.2, no. 10-70 Bogotá	283-0900	Sanitary Engineer
Del Valle University (U. V.) Environmental Sanitation Section’	Sanitary Engineering Study Plan	Ciudad Universitaria Melendez Cali	393-041/45	Sanitary Engineer

Sanitary Engineering Study Planning		Valle PO Box 25360		
District University, Francisco Jose de Caldas, Social and Community Development Institute (IDEMCO)	Environmental Sanitation Technology	Carrera 8ª. No. 40-80 Bogotá PO Box 8668	88-7111	Environmental Sanitation Technician

Table 5.11: Existing graduation courses in Chile

Institution	Course	Address	Telephone	Title Issued
Chile University Physical and Mathematics Science School	Civil Engineering with specialization in Sanitary Engineering	Avenida Libertador Bernardo O'Higgins 1058 Santiago	69-61424	Civil Engineer

Table 5.12: Existing graduation courses in Mexico

Institution	Course	Address	Telephone	Title Issued
National Polytechnic Institute (IPN), Technology Interdisciplinary Professional Unit (UPIBI)	Environmental Engineering	Avenida del Acueducto s/n Barrio de la Laguna Ticomán, 07300, PO Box 7574	754-4079	Environmental Engineer
Puebla Autonomous University (UAP) Civil Engineering School (EIC)	Sanitary Engineering	Calle 4-Sur no. 104 72000	45-8181	Civil Engineer
Metropolitan Autonomous University (UAM), Metropolitan Autonomous University Azacapotzalco (UAM-A)	Environmental Engineering	Edificio M. Ávila, Calle 90 N.de Juárez, México DF 53390, PO Box 325	576-3390	Environmental Engineer

Table 5.13: Existing graduation courses in Panama

Institution	Course	Address	Telephone	Title Issued
Panama Technology University (UTP) Civil Engineering School (FIC)	Civil Engineering with specialization in Hydraulics and Sanitary Engineering	Ciudfad Universitaria Octavio Méndez Pereira El Dorado, PO Box 6-2894	63-8000	Civil Engineer

Table 5.14: Existing graduation courses in Peru

Institution	Course	Address	Telephone	Title Issued
Santiago Antunez de Mayolo Ancash National University (UNASAM) Environment Sciences School	Environmental Engineering	Av. Centenario 200 Huaraz Ancash PO Box 70	72-1452	Environmental Engineer
Engineering National University (UNI) Environmental Engineering School (FIA)	Sanitary Engineering	Av. Tupac Amaru s/n Lima 25 PO Box 1301	(51 1) 481-1070	Sanitary Engineer

Table 5.15: Existing graduation courses in Venezuela

Institution	Course	Address	Telephone	Title Issued
Venezuela Central University Sanitary Engineering Department, (UCV), Engineering School	Civil Engineering with specialization in Sanitary Engineering	Ciudad Universitaria Los Chaguaramos Caracas, 1050-A	619811	Civil Engineer with specialization in Sanitary Engineering
Lisandro Alvarado Center-Western University (UCLA) Civil Engineering School (EIC)	Civil Engineering	Carrera 19 and Calle 8 Barquisimeto, Lara 3001, PO Box 400	51-413665	Civil Engineer
Eastern University Anzoategui Venue (UDO) Civil Engineering Department	Civil Engineering	Carretera Negra Puerto de laa Cruz Anzoategui	81 - 663827	Civil Engineer
Zulia University (LUZ) Civbil Engineering School	Civil Engineering with specialization in Sanitary Engineering	Av. 16, entre Calle 67 aand 69 Maracaibo PO Box 4003	61-512209	Civil Engineer

5.7.2 Existing Post-Graduation Courses

Table 5.16: Existing post-graduation courses in Argentina

Institution	Course	Address	Telephone	Title Issued
Buenos Aires University Engineering School (FI-UBA) Sanitary Engineering Institute (IIS)	Post-Graduation in Sanitary Engineering	Paseo Colón 850 Buenos Aires 1063	34-6441	Especialization in sanitary Engineering

Table 5.17: Existing post-graduation courses in Brazil

Institution	Course	Address	Telephone	Title Issued
Oswaldo Cruz Foundation Public Health National School (FIOCRUZ-ENS) Water, Sanitation and Environmental Health Department (DSSA)	Public Health Engineering	Rua Leopoldo Bulhões 1481 Manguinhos Rio de Janeiro RJ 21041	(55 21) 280-9436	Sanitary Engineer
São Paulo University (USP) São Carlos Engineering School (EESC)	Master and Doctorate in Environmental Engineering Sciences	Cidade Universitária Armando Salles de Oliveira São Paulo SP, 05.508, PO Box 8191	(55 11) 211-0011	MsC. and PhD in Environmental Engineering Sciences
	Doctorate in Hydraulics, Water and sanitation			
São Paulo University (USP) Polithecnics School (EPUSP)	Post-Graduation in Hydraulics, Water and Sanitation	Cidade Universitária São Paulo SP O5508, PO Box 61548	(55 11) 211-0011	Doctor in Engineering (Waater Resources, Water and Sanitation)
São Paulo University (USP) Puiblic Health School HAS Environmental Health Department	Specialization in Environmental Engineering	Cidade Universitária Armando Salles de Oliveira São Paulo SP, 01458, PO Box 05508	(55 11) 211-0011	Certificate of Specialization in Environmental Engineering
Campinas State University (UNICAMP) Civil Engineering School (FEL)	Post-Graduation in Civil Engineering (Water Resources, Water and Sanitation)	Bairro Barão Geraldo Campinas SP 13081 PO Box 6166	(55 19) 239-1301	MsC. in Civil Engineering
State of Espirito Santo Federal University (UFES), Hydraulic, Water and Sanitation Department (DHS)	Post-Graduation in Environmental Engineering	Avenida Fernando Ferrari s/n Goiabeiras Vitória ES, 29000	(55 27) 227-4733	MsC. in Environmental Engineering
State of Minas Gerais Federal University (UFMG), School of Engineering (EEUFMG)	Post-Graduation in Sanitary Engineering	Avenida Antonio Carlos 6627 Belo Horizonte MG 30161	(55 31) 448-1000	MsC. in Sanitary Engineering
State of Paraiba Federal University (UFPb) Technology and Science Center (CCT)	Post-Graduation in Civil and Sanitary Engineering	Campus Universitário s/n João Pessoa, Pb 58100	(55 83) 224-7200	MsC. In civil Engineering with specialization in Sanitary Engineering
State of Rio Grande do Sul Federal University (UFRS) Hydraulic Research Institute (IPH)	Post-Graduation in Water Resources, Water and Sanitation	Avenida Paulo Gama s/n Porto Alegre 90040	(55 51) 228-1633	PhD. And MsC. in Water Resources, Water and Sanitation

Table 5.18: Existing post-graduation courses in Colombia

Institution	Course	Address	Telephone	Title Issued
Javerian Catholic University (PUJ) Interdisciplinary Study School (FEI)	Post-Graduation in Water, Sanitation and Environmental Development	Carrera 7A, 40-62 Bogotá	288-4700	MsC. In Water, Snitation and Environmental Development
Antioquia University (UdeA) Engineering School Sanitary Engineering Department	Post-Graduation in Environmental Engineering	Calle 67 no. 53-108 Ciudad Universitaria Medellín 1 PO Box 1226	263-0011	MsC. In Environmental Engineering
Colombia National University (UN) Engineering School (FI) Civil Engineering Department (FEC)	Post-Graduation in Environmental Engineering with emphasis on Sanitary Engineering	Ciudad Universitaria Bogotá D.E. Po Box 14490	269-9111	Either Msc. or Specialization in Environmental Engineering with emphasis on Sanitary Engineering
Bolivarian Catholic University (UPB)	Post-Graduation in Environmental Engineering	Ciudad Universitaria de Laureles Medellín PO Box 1178	250-2080	Specialization in Environmental Engineering

Table 5.19: Existing post-graduation courses in Chile

Institution	Course	Address	Telephone	Title Issued
Chilean Catholic University (PUC) Engineering School	Post-Graduation in Engineering Sciences with specialization in Environmental Engineering	Alameda 340 Santiago PO Box 114-D	222-4516	MsC. in Engineering Sciences with specialization in Environmental Engineering
Chile University, Medical Faculty Public Health School Environmental Hygiene Group	Post-Graduation in Environmental Hygiene	Independencia 1027 Santiago PO Box 13898	776-560	Specialization in Environmental Hygiene

Table 5.20: Existing post-graduation courses in Ecuador

Institution	Course	Address	Telephone	Title Issued
National Politechnics School (EPN) Post-Graduation Institute	Post-Graduation in Environmental Engineering	Calle Isabel la Catolica s/n Quito, PO Box 2759	553-699	MsC. in Environmental Engineering

Table 5.21: Existing post-graduation courses in Guatemala

Institution	Course	Address	Telephone	Title Issued
San Carlos University, Engineering Faculty, Regional School of Hydraulic Engineering and Water Resources (ERIS)	Centroamerican Masters in Sanitary Engineering	San Carlos University Ciudad Universitaria Zona 12	760-424	MsC. In Sanitary Engineering

Table 5.22: Existing post-graduation courses in Mexico

Institution	Course	Address	Telephone	Title Issued
National Politechnics Institute (IPN) Engineering and Archictecture Superior School (ESIA-IPN)	Science Masters with specialization in Environmental Engineering	Avenida del Acueducto s/n Barrio de la Laguna Ticomán 07300, PO Box 7574	754-4079	MsC. with specialization in Environmental Engineering
Monterrey Technology Institute and Superior Studies (ITESM) Graduation and Research Branch (DGI)	Post-Graduation in Environmental Engineering Control Systems	Ave. Garza Sada 2501 Sur Minterrey NL 64849	582-000	MsC. in Environmental Engineering
Nuevo Leon Autonomous University (UANL) Civil Engineering School (FIC)	Science Masters, with specialization in Environmental Engineering	Ciudad Universitaria Monterrey 74000 PO Box 298	76-4140	MsC., with specialization in Environmental Engineering
Yucatan Autonomous University (UADY) Civil Engineering School (FIUADY)	Post-Graduation in Environmental Engineering	Calle 67 x 60 Mérida 97000	248-000	MsC. in Environmental Engineering
Guadalaja University (UdeG) Public Health Sciences Masters (MSCP)	Post-Graduation in Public Health Sciences	Av. Juárez y E. Díaz de León Jalisco PO Box 2-751	250-370	MsC. in Public Health Sciences
Mexico National Autonomous University (UNAM), Post-Graduation Studies Division, Environmental Engineering Branch (DEPFI-UNAM)	Post-Graduation in Environmental Engineering	Ciudad Universitaria Mexico DF 04510 PO Box 70256 C.U.	550-5215	PhD. Or MsC. in Environmental Engineering
Veracruzana University (UV) Engineering Institute (II-UV)	Post-Graduation in Environmental Engineering	Ernesto Ortiz Medina no. 3 Xalapa 91020 PO Box 57	91-281-57404	MsC. in Environmental Engineering

Table 5.23: Existing post-graduation courses in Peru

Institution	Course	Address	Telephone	Title Issued
National Engineering University (UNI) Environmental Engineering School	Post-Graduation in Water Treatment and Waste Reuse	Av. Tupac Amaru s/n Lima 25 PO Box 1301	(51 1) 481-1070	MsC. in Water Treatment and Waste Reuse

Table 5.24: Existing post-graduation courses in Venezuela

Institution	Course	Address	Telephone	Title Issued
Venezuela Central University (UCV) Graduated Student Comission Engineering School	Post-Graduation in Sanitary Engineering with specialization in Water Quality and Environmental Engineering	Ciudad Universitaria Los Chaguaramos Caracas 1050-A	619811	MsC. in in Sanitary Engineering with specialization in Water Quality or Environmental Engineering
Zulia University (LUZ) Post-Graduation Division	Post-Graduation in Environmental Engineering	Av. 16, entre Calle 67 aand 69 Maracaibo PO Box 4003	61-512209	Msc. In Environmental Engineering

5.9 Financing[7,8] (Topic j)

Several estimates have been made on the resources needed, and the cost of providing, universal coverage of water and sanitation in the Region. According to UNICEF, it would require 52.2 billion dollars between 1990 and 2000 to provide universal coverage in water and sanitation. This sum does not take into account the rate of inflation during the period and the cost of operation and maintenance of facilities.

In 1985, the Latin American Office of the World Bank estimated that it would require 92 billion dollars in investment in the sector to achieve universal coverage by the year 2000. This figure included cost of training of personnel and sector organization. This investment plan also suggested that Bolivia, Dominican Republic, Haiti, Honduras, Nicaragua and Peru, would need to invest about 1% of their gross domestic product to that sector. Unfortunately evidence suggests the investments needed were not generated and allocated.

The Regional Plan of Investment in Health and the Environment (PIAS) proposed by PAHO, following the reintroduction of cholera in the Region, estimated a total investment of 115 billion dollars in sanitary infrastructure between 1993 and 2004 to achieve universal coverage of water and sanitation. It was proposed that the bulk of the financing (70%) come from national investments and the remaining 30% would come from external investments. This proved impossible in the period, given financial constraints and the choice by Governments to support other priorities.

The information provided by the countries is not sufficient to give an accurate account of the total investments in the sector during the period 1990-95. However, the preliminary indication is that the total investments in the sector for the period, do not nearly approximate the estimated requirement to meet the Mid-Decade targets for the goal of universal coverage by the year 2000 or 2003 as indicated in the Regional Plan of investment and other estimates. This means the present situation is likely to remain in the near future.

The principal total investments in the sector were reported by Argentina (US$ 800 million), Bolivia (US$ 271 million), Dominican Republic (US$ 787 million), Ecuador (US$ 542 million), El Salvador (US$ 140 million), Mexico US$ (1,928 million), Nicaragua (US$ 111 million) and Peru (US$ 955 million). In addition, information provided by Brazil and Chile indicated external investments of US$ 3.9 billion and US$ 229 million respectively. A probable estimate of all investments in the sector would probably be approximately US$12 billion for the period 1990-1995.

The information provided by the financing agencies indicated that the two largest investment banks, the World Bank and the Inter-American Development Bank, invested a total of US$ 4.27 billion during the period 1991-95, including US$ 1.58 billion in Mexico. The German Government (GTZ and KFW) reported spending US$ 111.3 million during the same period, and CIDA US$11.2 million in Central America. The Caribbean Development Bank reported spending US$ 53.9 million in water and sanitation projects in the Caribbean. This would indicate a sum of US$ 4.5 billion invested in the sector for the period under review. Other agencies that provided investment in the sector include JICA, USAID, UNICEF and the European Community (EEC).

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[7] data extracted from the 1990-1995 Evaluation provided by PAHO.
[8] figures include Caribbean countries as well.

Details of the individual country investments are shown in Table 5.25; Investments in Latin America and the Caribbean by the World Bank and the Inter-American Development Bank are shown in Table 5.26.

Table 5.25: Investments in water supply and sanitation during the period 1990 - 1995 (US$ million)

Country	Sector Investment			External Contributions	% of Total External Contributions
	Water	Sanitation	Total		
Argentina	515	285	800	335	42
Bolivia	146	125	271	195	72
Brazil	N/A	N/A	3,983	N/A	N/A
Chile	N/A	N/A	N/A	229	N/A
Ecuador	399	143	542	228	42
El Salvador	118	22	140	116	83
Guatemala	71	9	80	28	35
Honduras	200	85	285	218	82
Mexico	N/A	N/A	1,928	1,444	75
Nicaragua	111	N/A	111	174	66
Panama	38	4	42	9	21
Paraguay	44	12	56	31	55
Peru	823	132	955	N/A	N/A
Suriname	N/A	N/A	N/A	3	N/A
Uruguay	101	32	133	62	47

Table 5.26: Investments in water supply and sanitation in Latin America by major lending agencies (US$ million)

Country	World Bank		IDB		Total
	Year	Funds	Year	Funds	
Argentina	1991		1991-95	300	400
Bolivia	1992-95				46.5
Brazil	1992-95	46.5	1993-95	465	1,399
Chile	1991	934			50
Costa Rica	1993	50	1991	51	77
Ecuador		26	1994	136	136
El Salvador			1991	19	19
Guyana			1993	13.5	13.5
Honduras					100
Mexico	1991	100	1992-94	369	1,587
Nicaragua	1991-94	1,218	1992	47	47
Paraguay			1995	79.6	149.1
Peru	1993-1995	69.5			150
Uruguay	1991	150	1993	45	45
Total					4,270

For the countries that provided complete information on sector investments it is interesting to note an increase in the ratio of external contribution to the total investments in the country. These figures vary from 21% in Panama to 97% in Haiti, with an average of approximately 45% in comparison to 30% reported in the previous decade.

The investments in sewerage and sanitation continue to lag behind those made for water supply. The available information indicate that the sewerage and sanitation investments approximate 50% of the water supply investments during the period whereas to meet the demand in a 20 year time they should be 200% of the water investments.

Table 5.27 shows the projected investments by the countries for the period 1996-2000. Information on sewage costs and tariffs are shown in Tables 5.28 and 5.29.

Table 5.27: Projected investments 1996 – 2000 (in US$ million)

Country	Sewage/Sanitation		Total
	Urban	Rural	
Argentina	N/A	N/A	7,125[9]
Bolivia	347.8	43.7	391.5
Brazil	N/A	N/A	10,315[4]
Colombia	N/A	N/A	1,837[5]
Costa Rica	59.6	8.8	68.4
Ecuador	18.3	19.5	37.8
El Salvador	1	.4	1.4
Guatemala	463.4	30.9	494.3
Honduras	414.4	N/A	414.4
Mexico	1,386	560	1,946
Nicaragua	N/A	N/A	N/A
Panama	N/A	1.5	1.5
Peru	N/A	N/A	2,6926[6]
Suriname	N/A	N/A	N/A
Venezuela	811	155	966
T O T A L			26,294.3

Table 5.28: Sewerage tariffs (US$/m^3)

Country	Sewerage Tariff (Urban)
Argentina	0.18
Bolivia	0.22
Brazil	0.64
Costa Rica	0.99
Ecuador	0.55
Guatemala	0.02
Mexico	0.05
Nicaragua	0.07

[9,4,5,6] figures for water supply are included

Table 5.29: Unit cost (US$ per person)

Country	Sanitation		
	Sewerage Connnection	Septic Tank	
Argentina	340		700
Bolivia	137		40
Brazil	170	40	40
Costa Rica	231	58	46
Ecuador	7		
El Salvador	80		150
Guatemala	260		25
Mexico	92		33
Panama	192	129	30
Paraguay		70	
Peru		50	15
Suriname		263	263
Uruguay	24		

5.10 Information sources (Topic j)

AIDIS (Interamerican Association of Sanitary and Environmental Engineering)

Rua Nicolau Gagliardi, 354
05429-010 - São Paulo, SP
BRAZIL

Telephone : + 55 11 212-4080; 55 11 9137-7110
Fax : + (55 11) 814-2441
Email : aidis@unisys.com.br
Contact: Mr. Luiz Augusto de Lima Ponte, Executive Director

Topics covered:[10] a, b, c, d, e, f, g, h

Description:AIDIS is Region-wide, professional organization comprising various professional country organizations, to which local organizations are affiliated. Below it is given the list by country of the organizations the run the various country chapters, being noteworthy that over 500 organisations belong to the AIDIS network.

Format of information :
Internet: http://www.aidis.org.br/
Language : Spanish, Portuguese and English
Consulting or support services : Responds to requests for assistance in coordination development policies and plans of Regional countries.

CEPIS (Panamerican Sanitary Engineering and Environmental Sciences Center)

Panamerican Information Network on Environmental Health (REPIDISCA)

PO Box 4337, Lima 100
Address: Los Pinos 259, Urb. Camacho-La Molina, Lima 12
PO Box 4337, Lima 100
PERU

Telephone : + 51 1 437-1077
Fax : + 51 1 437-8289
Email : cepis@cepis.org.pe; mbryce@cepis.org.pe
Contact: Mrs. Marta Bryce Chief Librarian

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Asociación Argentina de Ingeniería Sanitaria y Ciencias del Ambiente
Presidente: Ing. JOSÉ LUÍS INGLESE
Belgrano, 1580-3er piso
1093 Buenos Aires
ARGENTINA
Tel: (54-11) 4381-5832/4381-7665
Fax: (54-11) 4381-5903
e.mail: aidisar@aidisar.org.ar

BOLIVIA
Asociación Boliviana de Ingeniería Sanitaria y Ambiental – ABIS
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Calle B. Vincentti, 608 - Sopocachi
Casilla Postal 7231
La Paz
BOLIVIA
Tel: (591-2) 41-4513
Fax: (591-2) 41-0335
e.mail: abiswwb@yahoo.com

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Associação Brasileira de Engenharia Sanitária e Ambiental – ABES
Presidente: Ing. ANTONIO MARSIGLIA NETTO
Av. Beira Mar, 216 - 13o. andar
20021-060 Rio de Janeiro, RJ
BRASIL
Tel: (55-21) 210-3221
Fax: (55-21) 262-6838
e.mail: abes@abes-dn.org.br

COLOMBIA

Asociación Colombiana de Ingeniería Sanitaria y Ambiental - ACODAL
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Cra. 15 No. 78-48 Ofic. 401
Santafé de Bogotá
COLOMBIA
Tel: (57-1) 621-3680/621-3690/621-3721/236-6886
Fax: (57-1) 618-1272
e.mail: acodal@colnodo.org.co

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INSUMA S.A.
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San José
COSTA RICA
Tel: (506) 383-4130/227-8216
Fax: (506) 226-5102
e.mail: insuma@sol.racsa.co.cr

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AIDIS - Capítulo de Chile
Presidente: Ing. ALEX CHECHILNITZKY Z.
Barros Errázuris 1954, Piso 10, Of. 1007
Providencia
Santiago
CHILE
Tel: (56-2) 269-0085/269-0086
Fax: (56-2) 269-0087
e.mail: aidischi@ctcreuna.cl

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Calle Mariana de Jesús y Carvajal
EMPA-QUITO
Apartado Postal 17-17898
Quito
ECUADOR
Tel: (593-2) 44-6324
Fax: (593-2) 45-3835

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Edificio ASIA 75a.-Avenida Norte No. 632
San Salvador
EL SALVADOR
Tel: (503) 225-2755
Fax: (503) 225-2755
e.mail: guillermo.umana@salnet.net

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Presidente: Ing. ADAN E. POCASANGRE COLLAZOS
0 Calle 15-46 - 4o. nivel - Zona 15
Guatemala - 01015
GUATEMALA, CA
Tel: (502) 369-3701
Fax: (502) 369-3703
e.mail: jgil@care.org.gt atención a Adán Pocasangre

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Asociación Hondureña de Ingeniería Sanitaria
Presidente: Ing. MIGUEL OMAR MONTOYA
1a. Ave. Calle El Obelisco
Apartado Postal 437 - Tegucigalpa
HONDURAS
Tel: (504) 227-3897/227-5995/96
Fax: (504) 37-8552
e.mail: sanaades@hondudata.com

NICARAGUA
ANISA - Asociación Nicaraguense de Ingeniería Sanitaria y Ambiental
Presidente: Ing. MARCELINO V. JIMENEZ

G.
Centro de Formación Tecnológica
Apartado Postal 4631
Managua
NICARAGUA
Tel: (505) 249-9013/265-3474/265-3618
Fax: (505) 249-9017/278-3378
e.mail: inaar3om@nicanet.nicanet.com.ni

PANAMA
Asociación Panameña de Ingeniería Sanitaria y Ambiental – PANAIDIS
Presidente: Ing. GETULIO CASTILLO
Apartado Postal 874715
Panamá 7
REPUBLICA DE PANAMA
Tel: (507) 269-5833/269-6525
Fax: (507) 269-5992
E.MAIL: panaidis@usa.net o getulioc@usa.net

PARAGUAY
Asociación Interamericana de Ingeniería Sanitaria y Ambiental - Sección Paraguaya, AIDISPAR
Presidente: Ing. GENARO CRISTALDO IBARRA
Mariscal Estigarribia, 796
esq. Tacuary - Asunción
PARAGUAY
Tel: (595-21) 44-4399/49-3995
Fax: (595-21) 44-9262

PERU
Asociación Peruana de Ingeniería Sanitaria y Ambiental – APIS
Presidente: Ing. JORGE SALINAS DE CÓRDOVA
Pasaje los Pinos No. 114 - of. 705
Lima 18
PERU
Tel: (51-1) 445-9336
Fax: (51-1) 241-0030
e.mail: apis@junin.itete.com.pe

URUGUAY
Sección Uruguaya de AIDIS
Presidente: Ing. VERO RIVA
Calle Soriano 1.613
Código Postal 11.200
Montevideo
URUGUAY
Tel: (598-2) 400-5196
Fax: (598-2) 409-5683
e.mail: ggose@adinet.com.uy

VENEZUELA
AVISA - Asociación Venezolana de Ingeniería Sanitaria y Ambiental
Presidente: Ing. RAFAEL DAUTANT
El Trigal Centro Calle Pocaterra No. 88-20
Quinta los Corales
Código Postal 2002
Valencia, Carabobo
VENEZUELA
Tel: (58-41) 42-1435
Fax: (58-41) 42-8028
e.mail: avisa@eldish.net

5.11 Case studies (Topic k)

5.11.1 The Colombian: ASAS (Solids-Free Sewerage) System

Design of the system

Criteria, parameters and methodology of the ASAS design were deducted from the observation, investigation and analysis of many different variables but mainly centred on three basic concepts: (1) the compliance of the technical criteria and parameters to social factors and behaviours, (2) the hydraulic integration of the intercepting tanks with sewers, and (3) minimum cost and simplicity as final goals.

ASAS Conceptual Premises

Social factors and behaviours.
For the conception and further development of the ASAS system, the following sociological and anthropological concepts were carefully taken into account:

Urban residential areas and small towns tend to be more homogeneous than heterogeneous in social-economical stratification and in cultural background and behaviour. This tendency increases when the social economical level decreases.

Culture is more determining in fixing living habits, including water consumption and personal and domestic hygiene. If and when the social and economic condition improves with time, basic habits stay almost unaltered. Urban communities of slightly different socio-economic levels also have the same basic habits.

In urban communities the economic situation changes very slowly within one generation (30 years), unless an external phenomenon induces change.

In urban communities of the lower levels, the average numbers of occupiers per house tends to coincide with the most frequent household. A typical household, with the average number of occupiers per house can, then, be taken as a unit that represents the community. The variations in the number of occupiers in different times of the year, which takes place in many household, does not alter the average.

The typical house in a given community are similar in type and number of plumbing fixtures. For low social-economical strata, the typical house is equipped with a shower and a pour-flush toilet (although some may have a tank water-closet), a sink and a wash trough or tray. A hand lavatory is rarely added. For other strata and non-residential users, houses include a higher number or other types of fixtures.

Conditionants for dimensioning sewers.
The following statements allow for the adoption of the discharge of the unit house as unit load and to compute the sewers design load on calculus of probability:

Since the average number of occupiers per household in low strata is greater than the number of fixtures, during peak hours all fixtures are used and produce the greatest possible discharge rate when a toilet is flushed. In upper strata, or where the average number of fixtures is greater than the average number of occupiers, a similar reasoning applies: the greatest possible discharge is related to the number of fixtures being used by the total number of occupiers.

Like all natural phenomenon, the probability that several houses producing their maximum discharge exactly at the same time is ruled by the law of probabilities. The simultaneity is conditioned by the intermittent in the use of the toilet.

Because of the reduced statistical probability in exceeding the design load, sewers can be designed flowing full, to obtain small diameters.

As a conclusion, the capacity of the ASAS system is guaranteed for the long range, more than a generation (30 years).

Conditionants for intercepting tanks.
The intercepting tanks design is based also on social concepts, and cost/efficiency criteria as follows:

It is more convenient to adopt one size of tank for the unit house, than to proportion tanks to the number of occupiers in every house because occupiers vary depending on the time of the year and over the long term. The unit tank size is adopted for the optimum period for desludging which is the one with the lowest combined costs of construction and desludging. (This optimum period was 6 years for the Cartagena, Granada and San Zenon projects and for other projects).

Since both construction and maintenance costs must be paid by subscribers, the lowest cost must correspond to monthly rates. The lowest rate corresponds to the lowest summation of monthly rates to amortize or depreciate the construction cost, and the monthly allowance to cover the desludging cost. (These estimates could involve complex financial variables. The simplest method is to work with arithmetic depreciation of construction costs. The cost of desludging is divided by the number of months of the corresponding period).

Although the actual occupancy of each house determines the real period for desludging its tank, the average period is the period of the unit house, and an average rate can be charged to all subscribers.

Possibilities and restrictions

Notwithstanding the original purpose of the system, and that it is more suitable for predominantly residential areas, the ASAS system is not exclusively used for marginal or urban residential areas of the lower social-economical strata.

Based on the ASAS technology and with proper design parameters, the system is applicable in areas of different social-economical conditions, and is accepting of commercial, industrial or institutional users. In these cases the non-residential users loads are proportional to the typical household. In larger towns, conventional sewers for commercial and industrial areas can be combined with ASAS for residential areas.

In any case, the ASAS is not recommended for dispersed homes, where low urban densities do not make it competitive with in situ systems, nor for steep areas in which access for cleaning intercepting tanks is difficult.

Minimum cost parameters

Minimum cost.
The minimum cost of the system obviously corresponds to the smallest possible intercepting tanks and the smallest possible pipe diameter. To determine that cost, iterative calculations are necessary because both tank size and pipe diameters are directly related to rates of flow and the characteristics of solids, but, concurrently, tank size and proportions determine the rate of flow due to the buffering action on toilet flushings and the characteristics of unretained solids.

Computations made in the Cartagena study, working with discreet particles of clay or lime (the omnipresent material in the areas under study) with specific weight of 2.65, led to a set of basic parameters for minimum cost of tanks and sewers. The particle size to which minimum cost parameters correspond is 0.02 mm.

Further verifications with prices in Cartagena and for other projects, including the pilot projects of Granada and San Zenón, proved that these parameters are still correct in spite of drastic changes in prices in Colombia throughout the years since 1982.

Unit load.
The unit load for sewer design was worked out for cylindrical tanks, which were adopted as being cheaper than rectangular tanks under the assumption that they would be prefabricated in massive production for the South-Eastern Zone and Pasacaballos.

The rate of flow of the unit load is produced by the simultaneous discharge of all the fixtures, that is, the toilet, the kitchen sink the laundry trough and the shower. Colombian faucets and shower valves discharge around 0.1 l/s each for normal inhouse service heads (8-10 m water head). For the three fixtures the compound discharge is, then, 0.3 l/s.

For the unit tank adopted for that project, (0.90 m diameter, 1.48 m length for average occupancy of 6.8 people per house) the maximum possible discharge increment was 0.028 l/s for tank water-closet flushings (17 liters) and 0.007 l/s for pour-flush toilets (4 liters). The compound rates are, therefore, 0.328 and 0.307 l/s respectively.

For rectangular tanks of equivalent capacity to the cylindrical ones, the maximum discharges are less for obvious reasons: they are wider at liquid level and produce less over-elevation of liquid level with toilet flushings.

Since there is so little variation in maximum discharge in relation to the type of toilet and tank shape, a conservative unit load of 0.328 l/s, rounded to 0.33 l/s, was then adopted as a basic parameter for ASAS design.

Simultaneity equation and design loads.
For the determination of the design load for sewers, different methods of figuring out the probability of simultaneous discharges were considered. In Angelo Gallizio's "Instalaciones Sanitarias", published in Spanish in 1964 by Editorial Cientifico-Médica from Barcelona, a system to determine water demand and drainage in large buildings was found suitable because it takes into account three parameters to reflect more precisely the buffering effect of the intercepting tanks: peak duration, interval between repetitive discharges and duration of discharge.

Gallizio's equation is:

$$\log A^{r-1} - \log B = \log Cr^{n}$$

where:

i = interval between repetitive discharges
t = duration of the discharge
h = duration of peak
A = i/t, (i, t in minutes)
B = h/i, (h, i in hours)
Cr^n = number of possible combinations of "r" units out of a total of "n".

The equation was adapted under the following considerations. Although the influence of toilet flushings on the maximum rate of discharge from intercepting tanks is small, they determine the actual maximum value, so the interval between uses of toilets was taken as "y".

The maximum discharge value prevails only for an instant, but to be conservative the approximate time for the tanks to evacuate the volume of one flushing was adopted for "t" values. Valves for "H" and "i" were based on observations and surveys.

The curve of simultaneity for 2 hours peaks, i = 10 minutes and t = 1 minute, is shown in figure 5.1. Tables with valves of n, r, r/n and the corresponding design flows, have been prepared. They are not included for reasons of space.

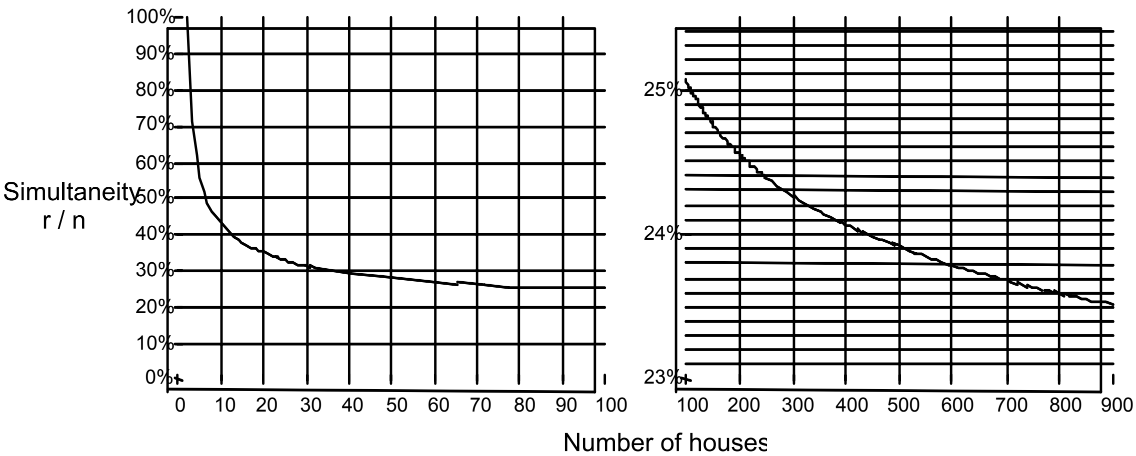

Figure 5.1: Simultaneity curve for sewer design flows

Sensibility analysis with different values for t and i, and with H varying between 1 and 2 hours produced very close values for r/n. This means that the discharge loads computed by this method and the capacity of sewers dimensioned will normally not be exceeded. As may be seen, the curve tends to be asymptotic to 23.5% values. With t = 30 seconds, it goes closer to 23%. For values of "t" approaching one second, the curve tends to drop to 4%.

It was considered too risky to use these low simultaneities even though the maximum discharge from intercepting tanks really last seconds, so the more conservative values, as in figure 3, were adopted for ASAS projects. The monitoring of the Granada and San Zenón pilot projects must contribute to elucidate this question. It might make ASAS even more economical.

Although sewers are usually laid above water table, infiltration flows are added to the design load with rates of 0.1 l/s/Ha for vitrified clay pipe and 0.05 l/s/Ha for plastic pipe. Storm drains are not permitted to be connected to tanks or sewers but 0.5 l/s/Ha are also added to design flows. These rates are half of the specified in Cartagena for conventional sanitary sewers. As a fact, infiltration flows can be reduced even more but the risk of abusive connections makes recommendable to include these flows.

Minimum velocity and slope.
The low content of fine particles in the effluents of intercepting tanks admits velocities as low as 20 cm/s in sewers. Nevertheless, it is not advisable to adopt a slope less than 0.1%, (equal to 1 cm fall each 10 m) because of practical installation limitations. This fall can be easily measured with enough precision with a hose level. (A hose level is a garden hose of enough length, with glass or transparent plastic tubes in both ends that is normally used in Colombia by masons and pipelayers. The hose is filled with water. The water level in both tubes is the reference to measure elevation falls).

This slope induces velocities of more than 20 cm/s for 3" and greater diameters for full flowing pipes and for unit load of 0.33 l/s. For 2" PVC pipes the minimum slope is a little less then 0.2%. Since velocities increase when pipes are not full, minimum slopes adopted were 0.2% for 2" pipes and 0.1% for larger pipes. Verifications with tractive force theory proved these parameters adequate for 0.02 mm particles.

Average number of occupiers per house.
This is the basic parameter to design the capacity for sludge and scum of the intercepting tanks. This parameter is determined dividing the population of the area by the total number of houses. Normally it should correspond to the number of occupiers of the most frequent house in terms of occupancy. It can be established with a census of population and houses or, more easily but less accurate, with a survey. Figures in Cartagena were 6.8 and in Granada and San Zenón, 5.76 and 5.78, rounded up to 5.8.

Discussion.
There is no logical reason to increase minimum slope. As for the particle size of 0.02 mm, it has proved adequate to produce the minimum ASAS cost in all projects. Besides, tanks to retain that size of particles are small enough. Only if experienced rates of accumulation of sludge and scum are greater than the ones deducted in the Cartagena project, tank dimensions are to be enlarged.

As may be seen, the number of free flowing fixtures have the heaviest weight in determining the unit load. For projects with different number and type of fixtures, this must be taken into account..

These basic parameters were also adopted for the Granada and San Zenon projects and the other projects designed by the consultant because general conditions were not as severe but similar to those of the Cartagena projects.

As a conclusion, it can be stated that basic parameters of ASAS makes this technology applicable for areas with any socio-economic level and that the numeric values set for the Cartagena project are applicable in places with more or less similar conditions to those in Cartagena, Granada and San Zenón.

Design

Location of sewers and intercepting tanks.

As shown in the typical layout of figures 2 and 3, sewers are localized on each side of the streets in the sidewalk area. The total length of the pipeline with this disposition is similar, to the total length of collectors located by the center line plus the branches of house connections. This is the most economical disposition because it allows lesser depths and manholes are eliminated.

Sewers interconnect house connection boxes, that serve for inspection purposes so the length is similar to the length of property fronts. In narrow streets, sewers can be located by the center line. Large diameter sewers are installed in the center of streets with the specifications of conventional sewers. Main sewers should run along the steepest ground slope. In practice, it is convenient to make several sketches, in order to obtain the lowest cost. Intercepting tanks must be localized according to the owner's preference but looking for easy access for inspection and cleaning and the shortest possible length for the outlet pipe preferably without changes of direction, as shown in figure 5.2 and 5.3. Drains from existing fixtures or the sanitary unit must also be considered.

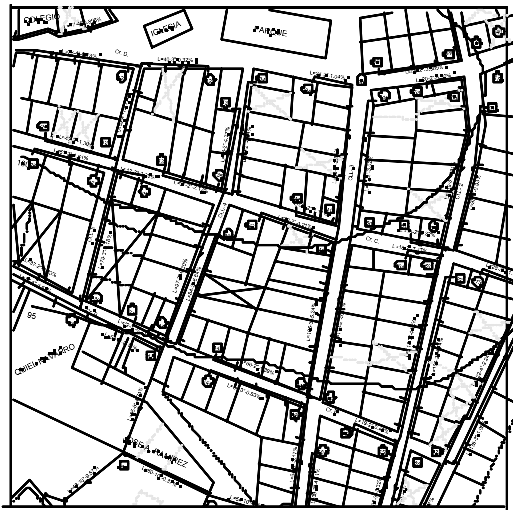

Figure 5.2: Typical layout

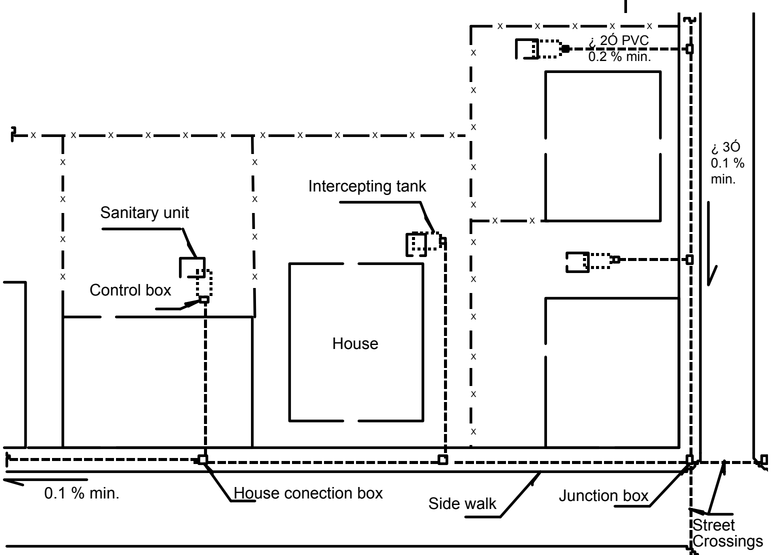

Figure 5.3: Detail of typical

Sewer pipes can be installed at minimum depths because little protection is needed against traffic loads. Since in low income communities traffic is scarce, in street crossings pipes can be laid embedded in concrete at a depth of only 10 cm below the gutter. The same is done at the entrance of garages. With a perimeter 10 cm embedding, the crossing of heavy vehicles will not crush up to 4" vitrified clay or plastic pipes if properly laid. For larger diameters, the minimum depth is 20 cm. With a depth of 50 cm or more, and an adequate laying of the pipes and compaction of the fill, concrete embedding is not required.

With 10 cm under the gutter and 15 cm curbs (commonly used in Colombia) the minimum depth in sidewalks can be of only 25 cm.

Design of sewers.
Sewers are designed with the aid of charts as for conventional sewers, but also utilise counting of houses and computing to match the corresponding design load with the simultaneity system. In the count, houses corresponding to empty lots can be estimated according to the average lot width. If pipe diameter changes in a given block, the house where the larger diameter is required can be easily located. This is not necessary but convenient to save some money, especially in long blocks.

Any formula may be used to calculate diameters. The most frequently used in Colombia is the formula of Manning.

Design of intercepting tanks.
Intercepting tanks are dimensioned using Stoke's formula for settling tanks, proportioning length, width and minimum liquid depth so the 0.02 mm particle will settle down with the maximum discharge rate which is the unit load for sewer design. Since this needs iterative calculations because the unit load depends on the tank surface, it is easier to start with a known tank design and adjust length if the number of fixtures is different. Disturbances caused by the vertical drains even with the sudden discharge of toilet flushings are neglected because the mean velocity of flow in tanks for the maximum discharge is less than 1 cm/s and the surge calms rapidly. Even if surge forces some solids out, it is only for an instant and mixes with discharges from other houses that do not carry solids according to the law of probability.

Tanks can have any shape provided the dimension in the direction of flow permits settling of solids. For projects where massive prefabrication is possible, cylindrical tanks may be more economical. If prefabrication is not possible, rectangular tanks are better and can be built with the participation of the community.

Figure 5.4 shows the tanks built in the Granada and San Zenón pilot project.

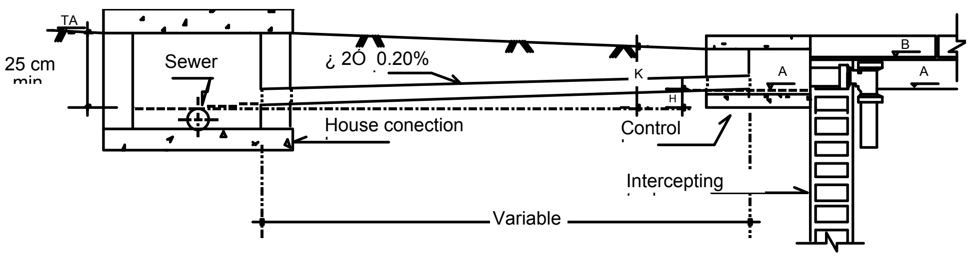

Figure 5.5: Typical house

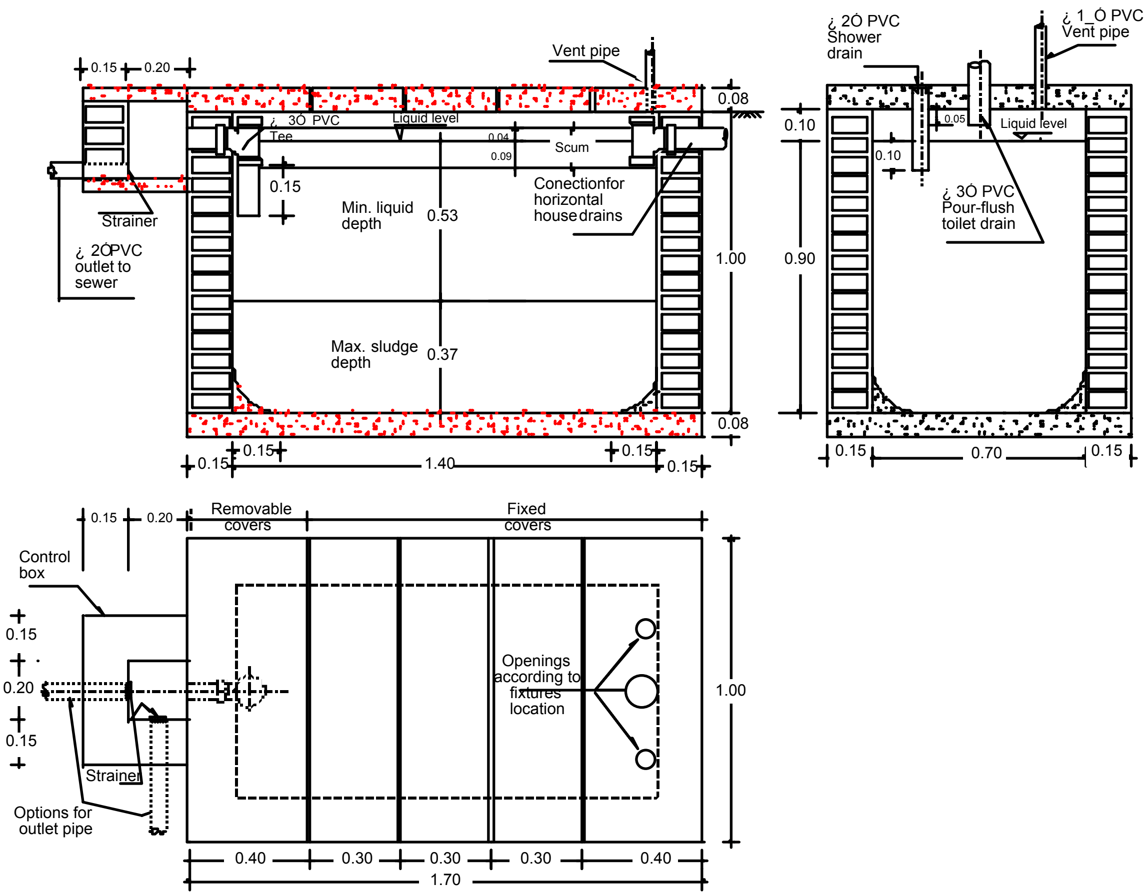

Figure 5.4: Intercepting tank and

Control box.
The intercepting tanks discharge into a small box provided with a strainer on the outlet pipe to retain any floating solid that might escape from the tank. (See figure 5.5).

The Sanitary Unit

The sanitary unit is an important supplementary component of ASAS projects in low income communities where houses usually do not have sanitary facilities.

The unit is a compact cabin (see fig. 5.6) with convenient space inside for a pour-flush toilet, manufactured in Colombia, and a shower with its floor drain. On the outside, a kitchen sink and a laundry trough or tray are backed to the walls. Both are provided with a hose-type faucets.

The unit is localized and oriented, and the fixtures are positioned according to the owner's preference but taking into account easy access from the house and the location of the intercepting tank.

The most economic position of the unit is over the intercepting tank so the fixture drains discharge vertically in the tank. The pour-flush toilet discharges 5 cm above the liquid level, the floor drain pipe discharges directly 10 cm under the liquid level to produce hydraulic seal (see figure 5.6). The kitchen sink and the laundry fixture have a common drain connected to the tank vent pipe through a trap.

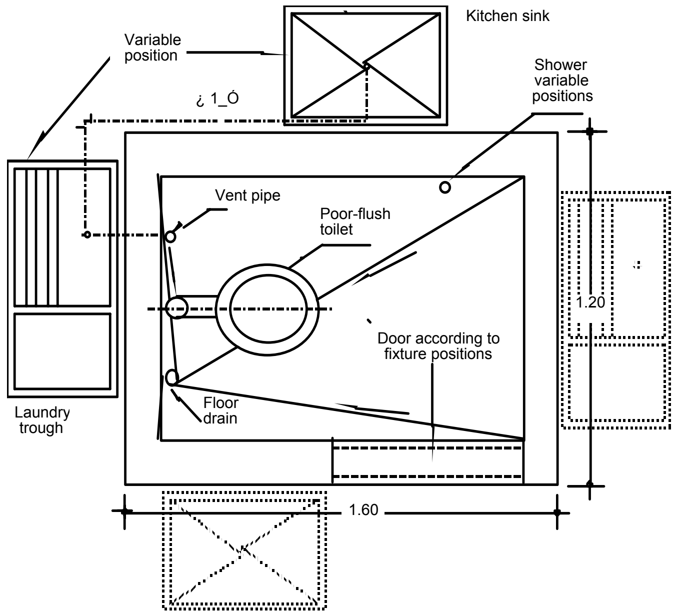

Figure 5.6: Sanitary unit

Maintenance

The maintenance of an ASAS system is practically concentrated on the cleaning of the intercepting tanks. Occasionally a control box will need removal of a small piece of cloth or other floating material. More rarely the removal of an accidental obstruction in a sewer will require attention. The desludging of the intercepting tanks can be done cleanly with suction equipment.

To avoid the use of large equipments and accumulation of desludgings in the disposal site, a program to distribute desludgings is recommended so a few tanks are cleaned per day or even per week. Desludgings can be disposed of also in a drying bed.

The relation of the volume of a tank content to the total daily discharge in a ASAS system (1 to 200 approximately) is so small that the desludgings can be disposed of in the treatment facility without problems. For San Zenón, for instance, the relation is 0.88 m^3 to 192 m^3/day. Even with several tanks cleaned per day, the effect of the added load of solids, DBO_5 and nutrients, is negligible.

Complementary Treatment

The intercepting tanks of the ASAS system retain around 80% of the solids and reduce BOD_5 in about 40 to 60%.

From field surveys, results for DBO_5 ranged between 72 and 184 mg/l with an average of 140 mg/l. For suspended solids results in the tank effluents when only toilet and kitchen sinks were connected to the tanks varied between 130 and 160 mg/l. At the sewers outlets, when the drains of showers and laundry troughs were included, the readings were very close to 40 mg/l. As compared to the sewage of the city, with an average of 250 mg/l for both BOD_5 and suspended solids, the reduction attained were between 40 and 60% for BOD_5 and around 84% for suspended solids.
For sludge accumulation rates, the average deducted was 10.18 dm^3/person/year. Scum formation was erratic. The average in tanks where some was detected was 3.51 dm^3/person/year.

For these reasons the effluents require only complementary treatment, like aerobic or facultative lagoons that may be designed with less organic loads than for sewerage. The effluents are also suitable for treatment in lagoons with water hyacinths or other floating plants. Possibilities extend to treatment through hydroponic systems and wetlands, or use for irrigation of suitable crops.

Cost of the ASAS

For the Cartagena project, at 1982 prices, cost of ASAS per house were Col $ 15,400 (US$ 42) for vitrified clay pipe sewers and Col $ 18,300 (US $ 50) for PVC, while the cost for sanitary sewerage was about Col $ 36,000 (US $ 98). The relation was 1 to 2.

In the San Zenon project, with prices of 1995, the cost of ASAS with vitrified clay pipe was Col $ 262.000 (US $ 325) and for sanitary sewerage about Col $ 800.000 (US $ 1000). Here the relation is 1 to 3. The equivalent costs per person are US $ 56 for the ASAS system and US $ 172 for conventional sewerage.

While the costs in Colombian pesos increased 17 times, for dollars of the United States the increase was 7.7 times. This distortion is due to the fact that the rate of internal inflation has been higher than the rate of devaluation of the peso in relation to the dollar.

The difference increases if house drains are taken into account. The ASAS system does not require additional expenses to build house drains if the sanitary unit is built over the intercepting tanks or very close to it. For sanitary sewerage the cost per house average 15 to 18% more for house drains. If the sewage treatment is included, the difference is even greater because for ASAS is less costly.

The important fact here is that the ASAS system is much more economical than the sanitary sewerage.

Observations on the use of sanitary units and fixtures, water consumption and operation of tanks and sewers were made in this lapse. Measurement of sluge and sullage were taken, and analysis of BOD_5, pH and suspended, dissolved and total solids were made on samples taken from septic tanks effluents and final effluents of outlets.

5.11.2 Condominium Sewerage Systems

Introduction

CAESB, the company charged with the water supply and sewerage in Brasília, capital city of Brazil, made a committed endeavour to providing basic sanitation to 100% of the city's urban population by the end of 1998. To achieve this objective, a methodology had to be developed for designing and building the sewer system in such a way as to allow large-scale use within a short time, keeping in mind the need to optimize projects and works to achieve the lowest implementation cost. For that purpose a condominium sewerage system (1) was employed, and a project plan for the implementation of the system was developed encompassing everything from the design, funding, invitation for bids, etc. to the implementation proper. This took into account tight time limits and availability of funds, but also what was required to meet the fundamental requirements for the implementation of the system.

The Condominium Sewerage System

The condominium sewerage system displays throughout its phases quite different characteristics from the conventional sewerage. Among them, the intensive participation of the people in the process, from choosing where the pipes will be located to the participation in meeting system costs and going as far as participation in the systems maintenance (2).

In terms of the engineering plan, the main difference between the condominium sewerage and conventional systems resides in the fact that in the conventional system each household is individually connected to the sewerage, while in the condominium sewerage system, several households are interlinked, forming a condominium sewerage branch, that will in turn be connected to the sewerage, called sewer mains (2). The branches may be inside or outside the lot, as shown in the next figure.

When designing the system, the location of the branch is discussed with the users, who opt for a solution and bear the consequences of such decision in terms of cost and operation.

Background

The participation of end users in the process of the condominium sewerage system implementation, results in an additional factor to be considered which is traditionally ignored in the implementation of conventional systems. Such participation before and during the work implies the need to have a flexible piping design, since the end users' decision may alter it, leading it to be redesigned as the work progresses.

Thus, when designing the system and before starting the works, there is an initial difficulty that is the definition of the condominium sewerage branch itself. As a rule, when the plans are made the branch has not yet been discussed with the end-users, leading the draftsman to make an estimate of its layout and depth and designing the sewer mains accordingly. This fact results in a certain level of inaccuracy in the plan that prevents is total optimization in relation to the eventual community option, since the draftsman ends up working with a certain degree of safety, always imagining the worst case scenario.

On the other hand, any professional who had the opportunity to participate in the planing, construction and operation of such a sewerage system will have seen the final difference between the plan and the works built, particularly because of the natural difficulty of foreseeing in the plan all sorts of interference and peculiarities arising throughout the works. The solutions found to the problems will many times no longer count on the participation of draftsmen. They will often lead to improvised solutions, not always the most adequate for the designed system.

When working with condominium sewerage systems and striving for optimization, both in terms of layout and depth, the divergences appearing in the works may have material bearing on the final result of the system, implying costs above those initially desired.
From the above it became clear that there is not much utility in having an execution project before starting the works, it being much more practical to draft the plan along its implementation.

Implementation Phases

In the methodology applied by CAESB, there is no longer a distinction between the plan and the work phases. Both are now part of an integrated process, based on the fact that the location and exact dimension of the sewer mains network will only be known after the community mobilization work. In other words when the brief for the condominium sewerage branch lines is prepared. Therefore, the execution project is made as the work progresses, by a team that resides at the works, adjusting the location and depths of the system to the condominium sewerage branch lines defined by the end-users. The suggestions are tackled by the draftsmen themselves, by adjusting the pipe network layout and depth according to the concept of the system.

According to this philosophy, the implementation of the sewerage system starts with the design of a basic project that serves to plan the start of the works, obtain funding and inviting bids. For the basic project all information needed to prepare the plan is obtained, as well as the positioning and preliminary dimensioning of the system, so as to reach an estimate of the network costs and length. There is no need to perform the whole topographic survey of the area, it is enough to have a few points indicating the overall sloping direction of the terrain. The basic project encompasses the following main activities.

Basic project activities

Preliminary data
Survey of the urban planning and topography of the area.

Definition of the project parameters (project horizon, populations, per-capita data, K1 and K2 rates, sewage/water rate, etc.)

Survey of the area
Survey of the area encompassed by the project, by visiting the greatest possible number of streets, always observing the natural run-off direction.

On the basis of the visit and topographic map, identification on the plan of drainage and occasional especial conditions that must be considered in the plan. (interference, sidewalk width, street grades, position of the lots, available areas, etc.).

For each group of households to be served, identification of the likely outlet of the condominium sewerage branch, according to the topography, to be connected to the sewer mains. Then comes the pre-positioning of the condominium sewerage branches that will collect the sewage from each group of households.

Positioning of the pipe networks
On the basis of the drainage and branch outlet plans the sewer mains are positioned so as to collect the sewage from the whole area to be served.

After positioning the pipe network, an assessment is made of the gradient of the area, either by a survey of the conspicuous points or of the available topographic maps, and the resulting depths needed for the implementation. The key factors in this definition are the minimum depths adopted for the branches and sewer mains (the latter on the basis of the minimum depth of the sidewalk and street under the traffic lane), the regional topographic conditions and the minimum grade adopted for the pipe networks.

Pre-dimensioning
The pipe network pre-dimensioning is performed by surveying the incoming discharges, stretch by stretch, on the basis of the lot use rules and calculation of the corresponding diameter using the grades defined for the respective stretches. (It must be pointed out that

over 50% of the networks are composed of condominium sewerage branches that require no dimensioning, since the minimum diameter most of the time is over-dimensioned for the number of households typically served by a branch). An electronic spreadsheet was created for the pre-dimensioning and eventual dimensioning of the sewage collection system, rendering hydraulic calculations much simpler, because it provides a budget of the services on the basis of the dimensioning already made with the parameters set forth for the system. The spreadsheet is filled out according to the discharge coming to the pipe network, and is later used in the execution project to make the adjustments arising from the information gathered during the works.

Budget and material survey
Once the system is pre-dimensioned, an estimate budget is made of the services to be performed. Such a budget is based on clearly defined execution criteria that must be adhered to during the works.

Invitation for bids
For funding and bidding purposes, the basic project must also foresee the preparation of the following documents: Technical description of the works, services specification, price rules for measurement purposes, plans and contracting rules. All documents must be prepared in an integrated way to harmonize the several layers of information with the final aim of the works.

Once the basic project is completed, it is possible to buy the materials calculated for the works and invite bids for its execution.

Phases of the execution project and works

For the works to be started, teams must be ready to follow up the services related to the several activities supporting the works. The dimensioning of such teams is proportionate the rhythm in which the system is to be implemented. The teams comprise:

Community mobilization team is charged with meeting users to choose the condominium sewerage branch layout. For instance, the team charged with meeting the users, is typically composed of two people, holds one meeting per day, usually in the evening. As a rule, each meeting is designed for 20 or 30 households, equivalent to approximately 150 users. A team is able to reach 3,000 users per month. Depending on the population to be assisted and the time horizon desired for the works, the teams are dimensioned accordingly.

The condominium sewerage branch brief team, charged with gathering the information needed before the discussion with users concerning the branch options for the group of households involved in each meeting (elevations involved, interference and possible layouts) and preparation of the brief on the solutions adopted by the users. Each team is composed by one technician and two assistants, enough people to follow the rhythm established by a community mobilization team.

The execution project preparation team, receive the briefs on the condominium sewerage branches and detailing the execution project of the sewer mains accordingly. As a rule, a draftsman and one technician are able to follow the rhythm of the works.

A works follow-up team, is composed of the typical works inspectors. It comprises one engineer for each 7,000 m of pipe network construction/month plus a sanitation technician.

Those teams operate in tandem at the works, performing the following activities:

Definition of the condominium sewerage branches
The definition of the condominium sewerage branch brief must include all information needed to build the branch, including the branch layout in relation to the group of households to be served, depth, positioning and types of special equipment, such as inspection chambers, connections, ramifications, etc., as well as the point and level of connection with the sewer mains. It must be pointed out that the condominium sewerage branch must take into account the level of connection of each household involved, so as to ensure its connection to the branch.

Topography of sewer mains
The definitive placing of the sewer mains, performed by the execution project team, should be based on the condominium sewerage branch brief. The sewer mains must be optimized in terms of discharge point and branch depth. To detail the sewer mains, the topography team must survey the stretches where they will be placed, adjusting the levels with the references left by the community mobilization team for the definition of the condominium sewerage branches

Execution project detailing
Adjusts the basic project with the briefs of the condominium sewerage branches and the works topography. Provides solutions to the obstacles faced. Details all aspects of the works, including location and type of flow-through chambers. The works of implementing the pipe network starts with the condominium sewerage branches, as the briefs become ready. Then the stretches of sewer mains where the branches are already built and will discharge are executed. Thus the pipe network is always placed in the exact depth defined by the branches.

Pipe network implementation sequence
The work is planned from upstream to downstream. The work must be organized in an integrated way, so that all scheduled activities: community mobilization, branch planning, topography, sewer mains and the work proper are executed in the sequence determined by the planning. The pace of the works will be determined by the detailing of the condominium sewerage branches that triggers the whole process.

Assistance to users
The community mobilization team stays at the works site until the final implementation of the sewer mains, answering all issues raised by the users.

Technical characteristics of the condominium sewerage system

All the phases of the process are carried out according to the predetermined technical conditions, allowing the goals set forth by the planning to be met at the conclusion of the works. The technical details below were developed for the topography and urban planning existing in Brasília, but should allow its application to any other urban area where single family lots prevail, with or without urban infrastructure. See Figure 5.7.

Backyard pipes, crossing backyard vacant areas placed inside the plots, with condominium being responsible for pipe maintenance;

*Garden pipes***,** crossing front yard of the plots, with condominium being responsible for pipe maintenance;

*Pathway pipes***,** placed on the pathways, with CAESB being responsible for pipe maintenance.

Condominium sewerage branches

The branch layout is defined by mutual agreement with end-users, always envisaging the path that will interfere less with the existing buildings. The level of each household connection is assessed and determines the depth of the condominium sewerage branch where all households pipes will discharge. Inspection chambers are placed at each end of each branch and at most every 60 m. They are generally made from precast concrete, in heights suitable to the varying ground depths. A service box is placed in each lot to be served for the user to connect.

The minimum depth adopted for the inside branch (within the lot to be served) is 40 cm and for the outside branch (outside the lot) is 70 cm. The inspection chambers have a diameter of 40 cm for depths up to 70 cm, and 60 cm for depths up to 110 cm. Inspection chambers are always placed where the branch changes direction.

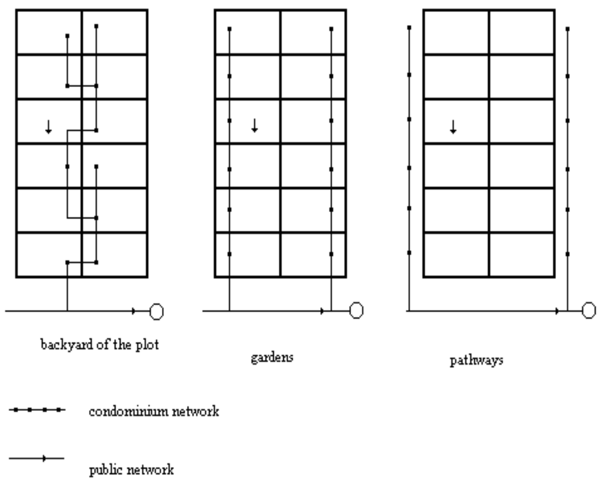

Fig. 5.7: Usual options for the condominium network in typical city blocks

Branches are in reinforced PVC pipes, with a minimum diameter of 100 mm. The minimum slope adopted is 0.005 m/m. No connections against the flow in inspection chambers are allowed. In the outside branches, the connections are made with a T to the outside pipe connecting to the service box inside the lot. In the cases where sewer mains are already planned in front of lots to be served by condominium sewerage, the branch will not be built, and the connections will be made directly to the sewer mains.

Sewer mains

Sewer mains have their initial depth dictated by the discharge level of the condominium sewerage branches connected to them. The minimum depth adopted for the sewer mains is 70 cm in areas without traffic, and 110 cm under traffic lanes. The connection of the branch to the sewer mains is preferably made in inspection chambers or manholes, and exceptionally by a saddle. Inspection chambers or manholes are placed at the beginning of each sewer main and at most every 80 m. They are generally made from precast concrete, in heights suitable to the varying ground depths.

Sewer mains are preferable placed on the sides of the street, under the sidewalk, where the branch may be replaced by sewer main itself. The use of shafts is preferred, and the direct connection to the bottom of the upstream service box or manhole is advised.

Budget and works criteria

To ensure that the works will comply with the initially desired cost, it is imperative that the services budget and their execution be based on common premises arising from the experience with similar works. Particularly during the works, it must be observed that the execution of the services must comply with the predefined criteria set forth in the contracting conditions. Among the criteria typically used in Brasília, the following are stressed:

Manual excavation for inside branches;
Box ditches for inside branch embankments;
1:3 embankments for ditches more than 1.30 m deep;
Mechanical excavation of the outside branches up to 50% of the ditch;
Refill: always compacted;
Lane crossings refilled with sand;
Restoration of the floor and wall linings to be made by the user;
In non-paved areas, inspection chambers must have a 10 cm leeway from the ground, to prevent stormwater from seeping in;
Standardized inspection chambers and manholes, according to their depths.

Projects already implemented

CAESB has been working with the condominium sewerage system for about 8 years, and has already completed over 500 km of pipe network under this system. The latest system built was the sewage collection system in Santa Maria, where the methodology presented here was adopted from the beginning.

Conclusion

The methodology presented aims to facilitate the implementation of large scale condominium sewerage systems, trying to take into account all the characteristics of this type of sewage collection, taking advantage of such characteristics so as to achieve a final result that is adequate both in terms of cost and quality, but that also makes use of all the possibilities offered by the participation of users in the process. The results attained by that method in Brasília have been very positive, demonstrating its large-scale applicability, thereby contributing to solving the serious problem of the lack of basic sanitation found in most developing countries.

Santa Maria's Condominial Sewerage

Introduction

Santa Maria was created in 1991 in the Southern section of the Brazilian Federal District with the aim of supplying adequate households for low-income people, see Figure 5.8. Presently its population is around 93,000 people, being planned for a saturation population of 170,000 persons.

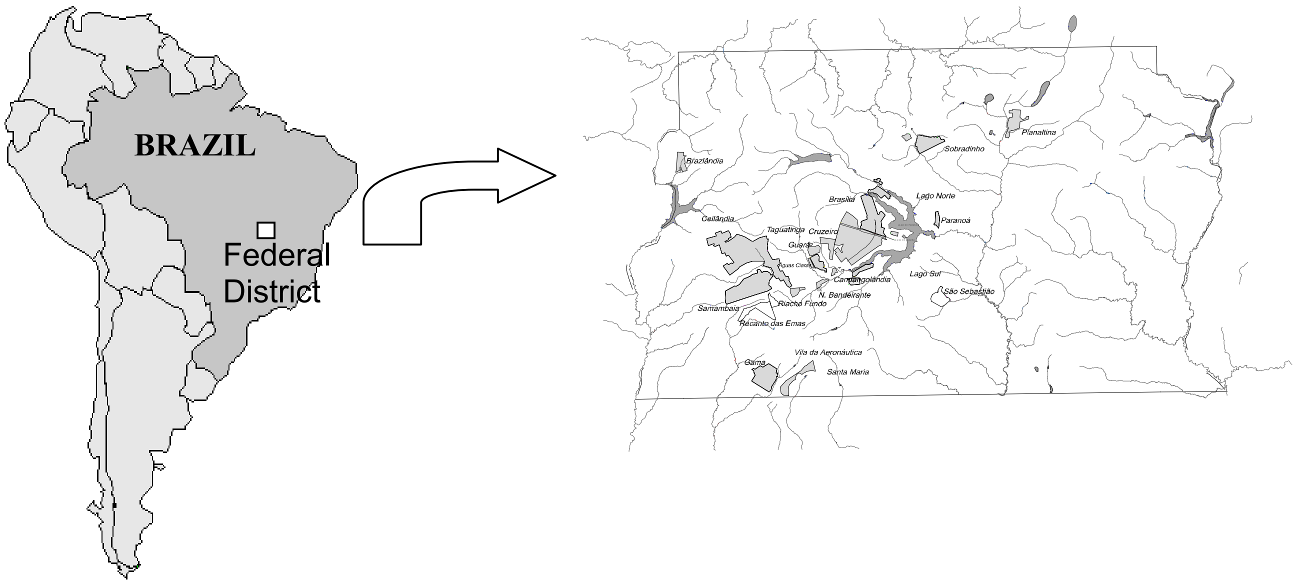

Figure 5.8: Location of Federal District

Federal District

The Santa Maria Sewerage Project, completed in 1998, has taken into account previous experience gained by CAESB in condominial systems, a fact that has caused important investment cost reductions. Actually per capita investment costs, including sewage collection and secondary treatment are around US$ 61. In addition its pipes and constructions have been designed with a view over future use for irrigation of the treated sewage, not only given predicted water scarcity but also as a measure to help develop the crops nearby.

Santa Maria's physical aspects

Santa Maria is placed alongside the Alagado and Santa Maria Creeks, with 7.5km of length and between 950m and 1550m of width, figure 5.9. The area's slope is below 5%, except close to the water courses where natural slopes are a bit steeper. Altitudes vary from 1120m to 1250m.

Soils are dry. Climate in Santa Maria is tropical, with mean temperature being 21.2ºC, the mean temperature being 19ºC in June and July, with mean temperature of 22.5ºC in the summer. Annual precipitation in the area varies from 1,120mm to 2000mm, with 92% from October to April.

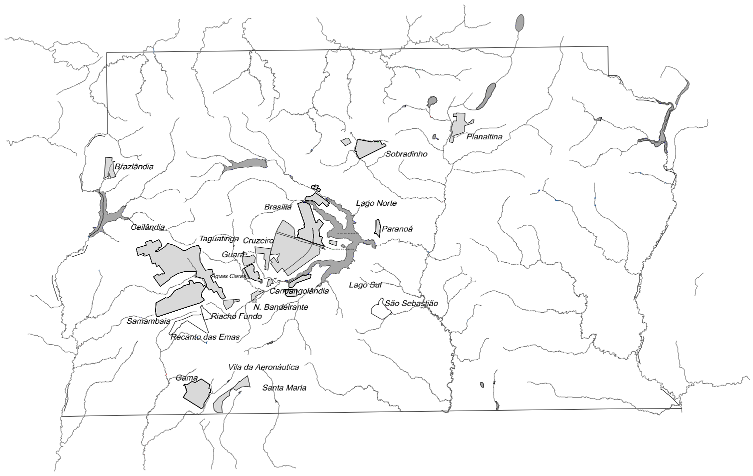

Figure 5.9: Location of Santa Maria.

The Alagado Creek's dry-weather mean flow is 414 l/s close to treated sewage disposal point; and the equivalent flow for the Santa Maria Creek is 192 l/s. Just downstream its sewage disposal point there is a CAESB's water intake, a fact that has precluded the Santa Maria Creek as a sewage receiving body, figure 5.10.

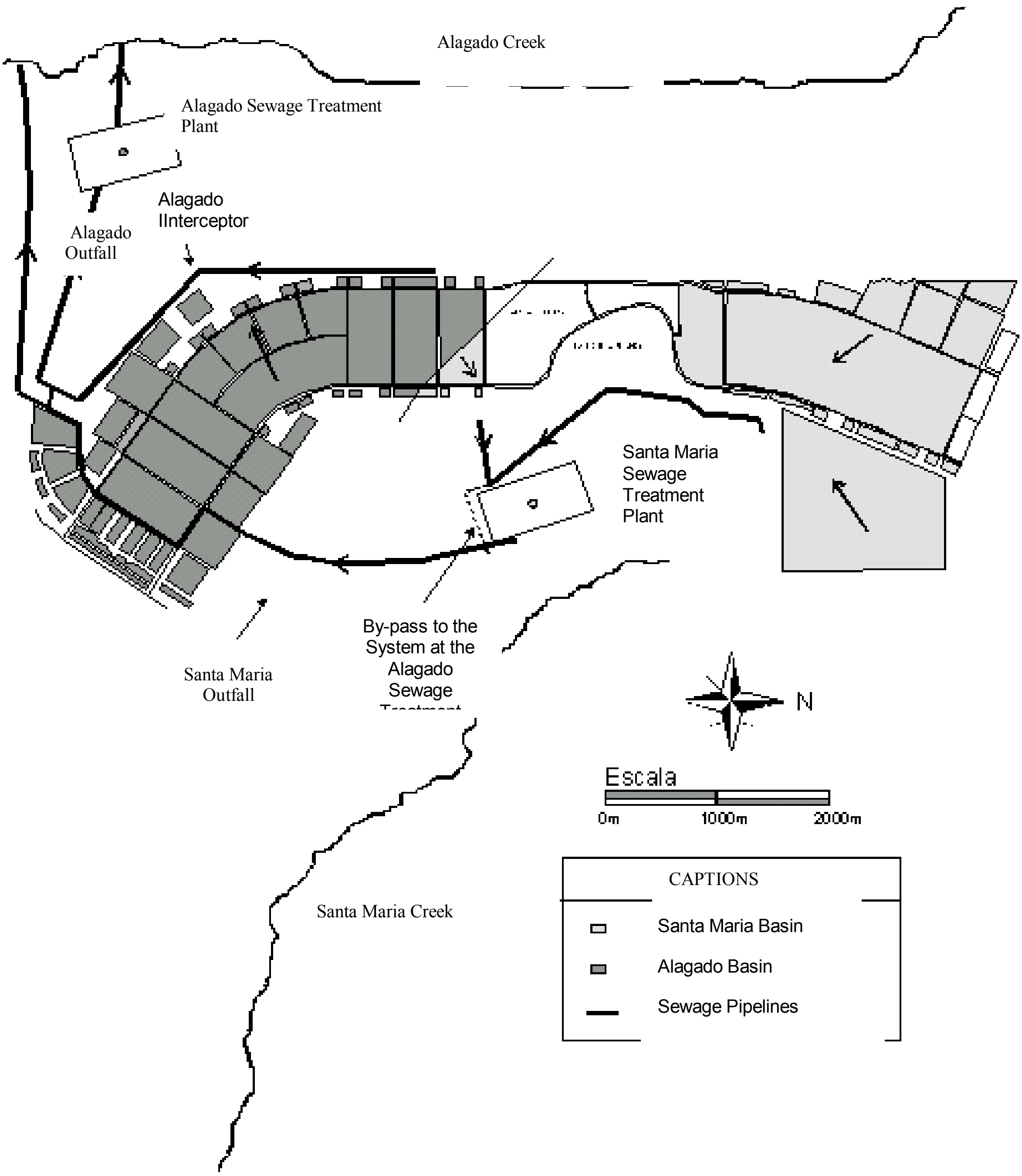

Figure 5.10: System's general plan

Sewerage designing procedures

The Santa Maria's condominial sewerage system uses the fact that the two above mentioned creeks receive flowing waters in the project area and as a result the overall system has been so split, figure 5.11.

Collection System

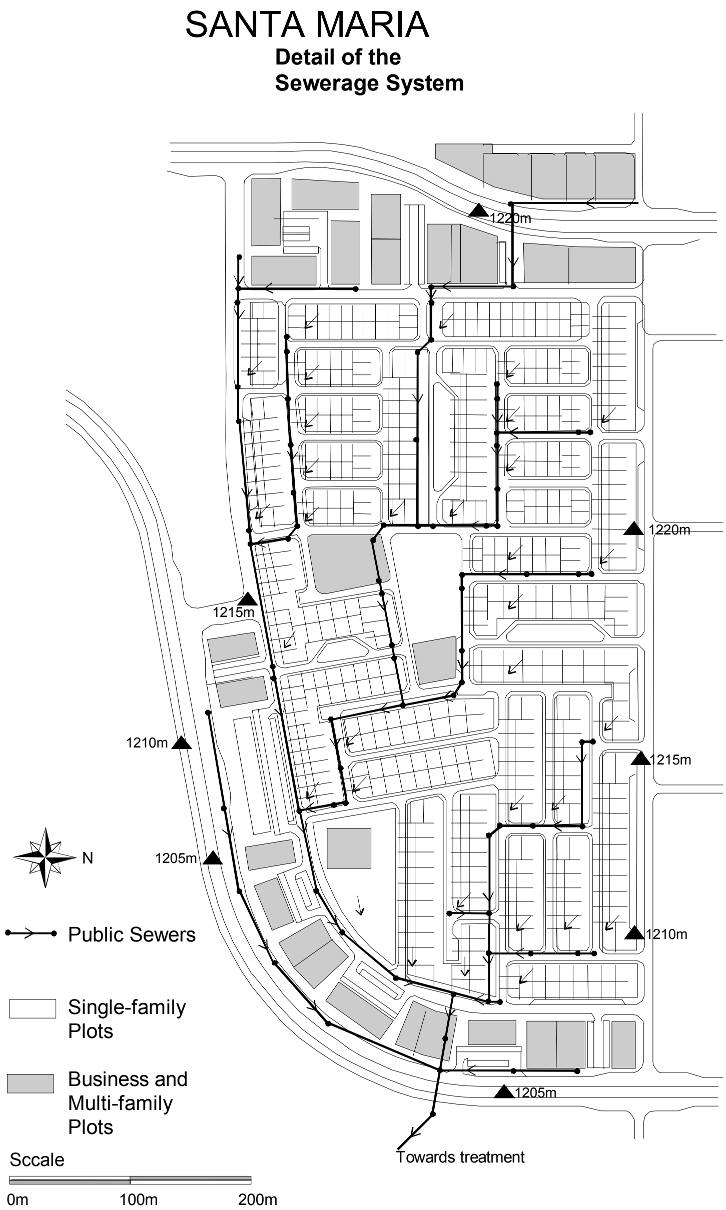

Figure 5.11: Detail of Santa Maria sewerage plan

Condominial Networks
645 condominium meetings, i.e, one for every block were held, with the participation of 7245 householders. The pathway pipe option has prevailed as for the condominium sewers.

Public Sewers
The design of the public sewers has followed Brazilian sewerage design codes which, nevertheless, have incorporate aspects that do not frequent in many other developing countries. Among these aspects it may cited the use of 100mm as the minimum diameter, the adoption of minimum tractive force (1.0 Pa) to determine the pipe slope, the use of the final flow (for the saturation of the area) to determine the pipe diameter and the substitution of the bulky conventional manholes by inspection chambers.

Treatment System

The sewage treatment's effluent were to follow WHO's recommendations for unrestricted irrigation, i.e, absence of helminth eggs and less than 1,000 FC/100ml. So, a set comprising two sewage treatment plants, each of them for 85,000 people (154 l/s) have been built, comprising the following units: anaerobic reactor, for a 11 hour detention time, high rate pond system for a 5 day mean detention time and soil disposal beds. Experience has shown that a further polishing pond is to be inserted to the treatment process.

Main results

In Santa Maria residential plots vary from 125m to 150m. Prices established by CAESB for the condominial sewers (the equivalent to housing connections in conventional systems) were the following:

Backyard pipes	US$95,00
Garden pipes	US$120,00
Pathway	US$175,00

This amount has been split up to 24 monthly parts and added to the water tariff after a grace period corresponding to the time interval that allows the householder to connect at is/her own expenses the plumbing outlet to the closest condominium sewer pipe's inspection chamber.

Table 5.30: Investment table

Parts of the System	Investments (US$)	% Total	Kind of Investments	US$ per capita (final flow)
Condominium Network	2,849,115	27.6	Private	17
Public Sewers	1,732,333	16.8	Public	10
Interceptors and Outfalls	973,193	9.4	Ditto	6
Treatment Plants	4,575,092	44.3	Ditto	27
Community Meetings	187,131	1.8	Ditto	1
Total	10,316,864	100.0		61

At last, It must be emphasized that the investment US$61 per capita is extremely cheap when compared with conventional systems (Table 5.30), being noteworthy also that full secondary treatment is part of the Santa Maria. System.

5.11.3 Aquaculture research and development program

Objectives

The objective of the Aquaculture Research and Development Program in the treated wastewater lagoons of San Juan, Lima, Peru, has been to study wastewater recycling by aquaculture, on the basis of bioengineering, sanitation and socioeconomic criteria, leading to the continuous enhancement of that type of integrated system to obtain high-quality products, so that the technique might be applied to the countries in that region.

The specific objectives in each phase were:

In the first phase (1983-86):

a. To assess the survival and growth of fish and shrimp in the tertiary, quaternary and pentanary wastewater lagoons in San Juan.
b. To prepare a research plan and to design an Aquaculture unit.

In the second phase (1987-90):

a. To implement the San Juan Aquaculture Experimental Unit and adjust the treatment system to supply it with water.
b. To manage the wastewater lagoons so as to obtain effluent suitable for aquaculture in terms of sanitation and fertility.
c. To determine the maximum fish production, introducing in the tanks wastewater lagoon effluent to stimulate the natural productivity, without generating environmental conditions harmful to fish.
d. To assess the quality of the fish bred and establish protocols allowing the certification of its suitability for human consumption.
e. To carry out a market survey to assess the acceptance of the tilapia bred in the treated wastewater of the Greater Lima.
f. To perform a socioeconomic survey to assess the potential of development of that system for the treatment of wastewater/aquaculture in tropical and subtropical conditions.

In the third phase (1991-98):

a. To develop a model to design integrated treatment/aquaculture systems and assess their feasibility under tropical and subtropical conditions.
b. To maintain and improve the San Juan Aquaculture Unit as a showcase of the sustainability of that module and transfer technology.
c. To carry out a special control of the quality of the treatment process and of the fish bred to verify the efficiency of the system after 10 years of operation.
d. To continue research to optimize the fish production achieved by breeding different fish varieties and species.

Methodology

Sponsored by the United Nations Development Program (UNDP), the World Bank (WB), the German Agency for Technical Cooperation (GTZ), the Pan American Health Organization (PHO) and the Government of Peru, several fish varieties and species were tentatively bred for 15 years in treated wastewater lagoons, both the hot and cold seasons of Lima's subtropical climate.

First phase

The experimental breeding took place between June 1983 and April 1984, using the San Juan tertiary, quaternary and pentanary wastewater lagoons. The survival and growth of "Nile Tilapia" *Oreochromis niloticus* and "common Carp" *Cyprinus carpio,* and "Malaysia shrimp" *Macrobrachium rosembergii* were evaluated.

During the experimental period a program to monitor the main physicochemical and microbiological characteristics of the water in the system was carried out. Also, a preliminary study of the sanitary condition of the fish was performed. Monthly controls of the weight and length of representative samples of the experimental population were carried out throughout that period. At the end of the experimental breeding, the lagoons were completely drained for the whole population to be harvested and to estimate the survival and yield.

Second phase
One of the recommendations from the first phase was the implementation of an Experimental Aquaculture Unit to continue research. For that purpose, CEPIS and the National Water and Sewerage Agency (SENAPA) took the technical steps required for a public bidding process. The unit was built by a private company under the supervision of CEPIS and SENAPA.

As soon as the unit started operations, four 154 and 122 day consecutive trials were carried out in winter and summer, respectively, between July 1988 and April 1990. Populations of Nile tilapia with average weight between 13 and 77 g were raised at densities varying between 0,2 and 5 fish/m^2. A food supplement based on a wheat byproduct was tried in the last two trials.

A set of 52 physical, chemical and biological parameters was frequently assessed in the treatment system, breeding tanks, sludge and fish during the four trial periods. Among the sanitary condition parameters, the following were included: total bacteria, total and fecal coliforms, Salmonella, sulfide reduction, Clostridium, E. coli bacteriophage, enteroparasites, polio virus, hepatitis virus, heavy metals, pesticides and polychlorinated biphenyls.

The bacteria concentration in the water of the breeding tanks was studied in relation to the resistance of the fish to prevent the entry of bacteria in their muscles. The quality of the fish was assessed according to classification proposed by Buras (1987), rating as “very good” fish with less than 10 bacteria per gram of muscle, "acceptable" those with 10 to 50 bacteria and "unacceptable" fish with over 50 bacteria.

A data matrix was designed to process the results, and the following were calculated:
- Survival rate (%),
- Growth rate (cm/day and g/day),
- Condition factor (W/L^3),
- Growth index (Pauly and Hopkins, 1983),
- Productivity (kg/ha/day), and
- Load capacity (kg/ha).

The growth rate was taken as the response variable and matched to the averages of each one of the parameters monitored. Later, multiple regression equations were devised and adjusted to models such as those described by (1985) and Pauly et al. (1988).

A tilapia market survey was carried out in the Greater Lima between May and September 1990, to assess the acceptance of the origin of the product, or "Live tilapia bred with treated wastewater", its price and demand. The survey encompassed four phases:
- Conceptual test (qualitative), to collect the first opinions from the public (housewives) about the new product "live tilapia".
- Product test (quantitative), to assess the acceptance of the product by potential consumers (housewives).
- Preliminary market test, to introduce the product in the market for different social strata.
- Definitive market test, to assess the acceptance of the origin of product "Live tilapia bred with treated wastewater ", its price and demand.

The results achieved in the trial breeding enabled a socioeconomic survey to be carried out, assessing the potential development of the wastewater treatment/aquaculture in subtropical areas such as Lima and to extend them to tropical areas (with year-round high temperatures). It encompasses the dimensioning of model tilapia breeding units, the calculation of the investment and operation budget and the cash flows for both climates. The economic and financial evaluation was performed on the basis of the Net Current Value (NCV) and the Internal Rate of Return (IRR). As a reference for the financial analysis a credit line was employed. The sensitivity analysis aimed to assess the NCV behavior in relation to varying selling prices, production costs, project sizes and cost of the land.

Finally, during this phase the social impact of the project was assessed as to the potential development of integrated systems, job generation, enlargement of the agricultural frontier and increase in the per capita fish consumption. The constraints for the development of that activity, as well as the health risks and environmental consequences were studied.

Third phase

As a result of the foregoing studies, an interactive spreadsheet model was developed to prepare projects integrating wastewater lagoons and tilapia breeding, including market, technical and economic information through related routines, resulting in the definition of the economic profitability.

The initial model had been significantly changed in 1997, using updated software to facilitate its handling by professionals and designers. This model was designed to compile, process and display information on the project profile in a way that is useful to dimension and budget the treated wastewater tilapia farms.

Also, in 1992 the San Juan Aquaculture Unit was enlarged to become a showcase unit and to ensure its self-funding. For that purpose three production tanks were incorporated, with 12,000 (tertiary lagoon), 11,000 and 15,000 m^2, thus allowing the smaller tanks to be dedicated to the maintenance and evaluation of new tilapia varieties.

In the period between 1991-97 routine controls of the major physicochemical and sanitary condition parameters were performed. From March to May 1998 a special control of the system and fish quality was performed, including 22 of the main physical, chemical and biological parameters, to confirm the efficiency of the treatment after 10 years of continuous operation.

In 1996 two tilapia types were imported from Panama to improve the Aquaculture Unit production: the red and silver tilapia from Panama. Both varieties were evaluated by means of experimental breeding performed between 1997 and 1998, with the following characteristics:

a. Comparative breeding of the red and silver tilapia
For 136 days between November 21, 1997 and April 6, 1998 2,000 alevines from the two kinds were bred separately in four 400m^2 tanks. The initial fish density was 1.25 fish/m^2, using tertiary effluents and only natural food.

b. Comparative breeding of the silver tilapia kinds from Panama and San Juan.
In the 180 days between April 20 and October 16, 1998 3,000 silver tilapia of the Panama and San Juan varieties, and a mix of both are being bred. For that six 400 m^2 tanks are being used, all of them supplied with tertiary effluents. The fish, initially at a density of 7.5 m^2, are being fed only natural food.

Results

From the first phase

The preliminary experimental breeding evidenced that the environmental conditions in the quaternary lagoons were satisfactory for the survival and growth of Nile Tilapia (*Oreochromis niloticus*) and the common carp (*Cyprinus carpio*), but not to breed Malaya shrimp

(*Macrobrachium rosembergii*). It was also established that the tilapia was the most resistant and accepted species, therefore it was selected for further investigation.

The preliminary microbiological, parasitological and toxicological tests showed that there were no apparent restrictions to the destination of the fish directly for human consumption. (Moscoso and Nava, 1988).

The wastewater lagoons ended up being unsuitable to breed fish, because the final harvest implied in draining them completely, thereby temporarily discontinuing their treatment function. All the same, it was very difficult to extract the fish due to the great accumulation of mud normally produced in lagoons. Finally, it was observed that the changes in flows that took place rather frequently in the system caused a deterioration in the environmental quality, affecting the development of the fish and in some cases causing their death. For those reasons, finally it was recommended that special fish breeding tanks be built, to be supplied with tertiary effluent from the wastewater lagoons.

The results of that preliminary phase were discussed by two panels of experts in Lima, Peru (1984) and Bangkok, Thailand (1987), and the recommendation was the implementation of an Aquaculture Experimental Unit to continue the research.

From the second phase

Implementation of an Aquaculture Unit
The Experimental Aquaculture Unit was built in 1987 on the sandy soil of a secondary lagoon located on the low side of the San Juan Wastewater Lagoon, and comprised the following facilities:

- a controlled-temperature laboratory for the reproduction and sexual reversal of the tilapia,
- six 100 m^2 service tanks,
- twelve experimental 400 m^2 tanks, and
- two production tanks, one 2.700 and the other 3.200 m^2.

The treatment system specially adapted to supply the Unit consisted in a set of wastewater lagoons, with two primary lagoons operating simultaneously and a combined 1.14 ha area connected to secondary and a tertiary lagoon, with 1.84 and 1.00 ha, respectively (Photo 5.1). The water volume was permanently adjusted according to the climatic conditions, to maintain the effluents with fecal coliform levels below 10,000 per 100 ml.

Efficiency of the treatment system
Table 5.31 shows the average value of the physico-chemical parameters measured in the treatment system, during the two years of experimental breeding. The treatment system allowed the reduction of the BOD levels to ranges between 112 and 68 mg/l, and the total ammonia ranged from 2.62 and 0.45 mg/l, amounts tolerated by the Nile Tilapia.

Photo 5.1: View from the treatment system (stabilization pond)

Table 5.31: Average values of the physico-chemical parameters measured in the lagoon system throughout the duration of the trial, from July 4,1988 to April 9, 1990 (mg/l)

Parameter	Raw	Primary	Secondary	Tertiary
COD total	562	202	183	171
BOD $_5$ total	278	53	91	80
TSS	270	96	111	103
VSS	229	88	100	94
P total	7.70	4.73	4.76	4.54
N organic	19.25	8.16	10.58	10.55
Nitrates				0.72
Nitrites				0.43
Nitrogen amoniacal	47.49	22.15	7.12	1.78
Alkalinity total	260	210	154	135
Chlorofile A (ug/l)	0	943	1139	1113
Coliforms total.	1.72E+09	1.53E+07	3.40E+05	2.03E+04
Vibrio cholerae	2.70E+03	9.20E+00	8.00E-01	1.60E-01
Salmonella				4.30E+01

The wastewater treatment lagoon system proved to be efficient to ensure good quality to the water to be used in the aquaculture. Figure 5.12 shows the removal of fecal coliforms from the system. Therefore, the treatment system monitoring is basically geared to ensuring the quality of the effluents to be used in aquaculture. Water flow and temperature (maximum and minimum) are the minimum recommended daily measures; BOD_5 and fecal coliforms are the minimum recommended monthly measures, both for the affluent and effluent of the system.

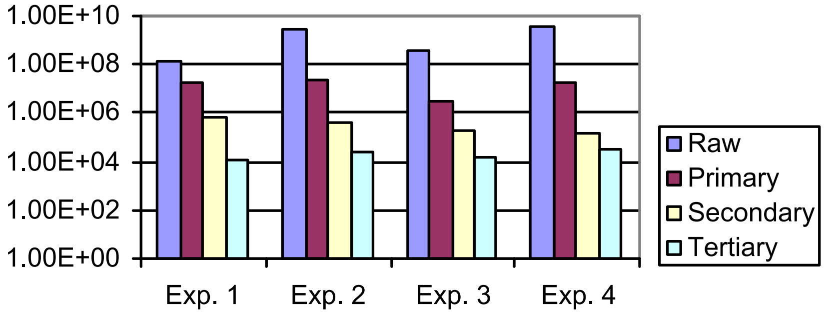

Figure 5.12: Fecal Coliform Removal

It was also found that the distributed flow system, used to estimate the retention period in wastewater lagoons (Sáenz 1987), serves as an efficient tool to design the operation of systems involving the use of effluents in activities such as aquaculture, in which the main restriction is the allowed level of bacteria.

The prediction regression equation derived for the effluent bacteriological quality is as follows:

$y = 0.6528 + 0.8853 x$, where:

x = log of predicted value (fecal coliform);

y = log of observed value fecal coliform.

$R^2 = 0.9083$

$n = 46$

confidence interval = 99%

Sanitary quality of the fish

The physicochemical characteristics of the tertiary effluent used to feed the aquaculture tanks are presented in Table 5.32.

Table 5.32: Physical chemical qualities of the effluent used in the aquaculture tanks during the trial.

Parameter	Unit	Experiments			
		1	2	3	4
Temperature	°C (a)	19	27	18	25
pH	(a)	7	10	9	10
DO (minimum)	mg/l (b)		0	2	1
COD total	mg/l	173	200	141	185
COD soluble	mg/l	45	56	33	57
BOD total	mg/l	73	110	65	84
BOD soluble	mg/l	16	18	7	21
TSS	mg/l	107	121	77	111
VSS	mg/l	102	109	69	97
Alkalinity	mg/.	127	128	134	150
Clorophile-a	ug/l (c)	1554	914	1144	668
Fitoplancton (dry mat.)	mg/l	104	61	76	45
Transparencie Secchi	mm (b)		18	17	15
P total	mg/l	4.73	5.31	3.23	5.37
Ortophosphate	mg/l (d)	1.48	0.99	2.01	1.65
N total	mg/l	14.90	15.00	9.80	15.30
N organic	mg/l	11.20	11.30	8.50	11.80
N amoniacal	mg/l	1.99	2.59	0.50	2.50
N from nitrites	mg/l	0.39	0.62	0.07	0.72
N from nitrates	mg/l	1.35	0.44	0.71	0.23

(a) In the first trial the measurements were taken between 9:30 and 11:00 a.m., while in all others they were taken between 6:00 a.m. and 2:00 p.m.
(b) No measurements were taken in the first trial.
(c) The samples were collected in the surface in the first trial, while in all others they were taken from the water column.
(d) The first trial figure corresponds to the last eight weeks.

As can be observed in Table 5.33, in three trials 100% of the fish were rated "very good". Only in the third trial 6% of the fish were rated "unacceptable", according to the classification proposed by Buras (1987), that rates "good" as fish with less than 50 bacteria per gram of muscle. The increase in unacceptable fish was caused by a deliberate increment in the level of fecal coliforms, raised above 10^5 in the effluent, allowing a determination of the limit of effluent quality that can be used in breeding tilapia. Once the limit is exceeded, the tilapia's immunological system is impaired and the bacteria penetrate in the muscle. Also, the ability of that fish to self-depurate was observed, whenever the coliforms were reduced to the recommended level for a minimum period of 30 days. This means that in the case of an "accident" overburdening the treatment system, the sanitary condition of the affected fish could be recovered. Photo 5.2 shows a fish catchment from the treatment system.

Photo 5.2: View from the fish catchment

Table 5.33: Sanitary condition of the fish, according to the classification proposed by Buras (1987), in percentage

Quality	Concentration of bacteria per gram of muscle	Experiment			
		1	2	3	4
Very good	0 – 10	100	100	86	100
Aceptable	10 – 50	0	0	8	0
Reprovable	Over 50	0	0	6	0

In principle, the sanitary condition of the fish was good when the water in the tanks had a 1 x 10^4/100 ml coliform level and also a decrease of at least one logarithmic order between the fecal coliform load of the treatment system effluent and the aquaculture tanks. For that reason, the maximum level of fecal coliforms in the effluent should be 1 x 10^5/100 ml. This threshold would be one logarithm above the World Health Organization recommendation (WHO, 1989), since it corresponds to a value of 1 x 10^4 for the fish breeding tanks.

In two years of sanitary control, no pathogenic bacteria, parasites or viruses were found in the fish bred. The levels of heavy metals, pesticides and PCBs were well below the limits established. According to the warm water fish criteria employed by the International

Committee of Microbiological Specifications of Food (ICMSF, 1983), the fish bred in the experimental conditions were considered fit for human consumption.

Fish production

The database, ordered according the initial fish biomass, is shown in Table 5.34. Those results witness the possibility of having a commercial aquaculture activity associated to the efficient use of wastewater from treatment lagoons.

Table 5.34: Database ordered according to the initial biomass

Experiment	Tank	Density (#/m2)	Biomass (kg/ha)		Survival (%)	Growth rate		Productiv. Kg/ha/day
			Initial	Final		cm/day	g/day	
2	3	0.20	47	436	91.9	0.114	1.91	3.47
2	9	0.20	51	483	100.0	0.108	1.93	3.86
2	10	0.20	51	411	90.5	0.105	1.80	3.22
4	6	0.20	129	468	82.4	0.088	1.95	3.02
2	12	1.00	202	1,898	91.9	0.104	1.66	15.14
2	2	1.00	236	1,637	84.1	0.100	1.53	12.51
2	11	1.00	238	1,895	99.5	0.098	1.49	14.79
2	8	3.00	672	3,262	95.0	0.071	0.82	23.12
2	5	3.00	684	3,476	82.5	0.081	1.05	24.93
2	4	3.00	708	3,379	89.5	0.078	0.91	23.85
4	3	1.50	792	3,080	95.5	0.080	1.45	20.43
2	6	5.00	1,025	4,610	87.6	0.064	0.76	32.01
2	1	5.00	1,090	4,042	82.6	0.062	0.68	26.35
2	7	5.00	1,150	4,170	86.2	0.061	0.66	26.97
4	4	1.50	1,389	3,260	85.2	0.064	1.45	16.70
4	5	1.50	1,515	3,386	84.1	0.064	1.49	16.71

Photo 5.3: Typical fish from the San Juan Ponds

In subtropical climates like that of Lima, the growth of the Nile Tilapia is positive and similar to that obtained in tropical zones only in summer months. Tilapias with an initial weight of 60g can be bred during 112 warm days at a density of 2 fish/m^2, to reach a market weight of 250 g. The maximum productivity of the aquaculture tanks in summer was 30.79 kg/ha/day, obtained from an initial biomass of 960 kg/ha. Photo 5.3 shows the typical size of a fish from the San Juan Ponds. The maximum permissible load was set at 4,400 kg/ha, achieved solely with the natural food produced in the breeding tanks by adding the effluent of the wastewater lagoons. In view of the high algae production under those conditions, between 1,573 and 718 mg/l chlorophyll A, it was found that in practice the addition of artificial feed as a complement cannot increase the load capacity of the tanks. Pillay (1990) comments that in Brazil the tanks fertilized with organic complements achieved high production of tilapia, such as 1.35 MT/ha, without the need for complementary feed. Lovshin (1977) report that in all-male tilapia populations 3.2TM/ha of tilapia were harvested using supplementary feed.

In winter, when the water temperature drops to 17°C, it is not possible to increase production, because of the tilapia lower growth rate. Balarin and Hatton (1979) point out that the lowest temperature limit for the tilapia to grow is between 17.2 and 19.6°C. For that reason, it is proposed that the fish be stored in pre-winter breeding until the temperature increases.

The survival achieved in the second trial was 88%, an amount considered normal in tilapia breeding. Also, the figures of 80 and 64% achieved in winter breeding, produced more evidence regarding the fragility of that species when handled in cold seasons.

The production in climate conditions such as those in Lima would have three phases:

a. Reproduction, sexual reversion and summer pre-breeding, during the warm period from December to April, until they weigh 2 g.
b. Winter pre-breeding, during the cold period from May to November, until a final minimum weight of 60 g is reached.
c. Production, during the warm period from December to March, until the market weight of 250 g is reached.

In tropical areas, breeding can be continuous, shortening the second phase by three months. Those three phases would take place simultaneously, to achieve three staged breeding rounds a year.

Market survey

The results of the market survey for live Tilapia, bred in the wastewater of the Greater Lima, can be summarized in the following points:

- The introduction of this species in the Greater Lima market was achieved, and it has excellent selling potential, mainly because it is offered alive, something consumers perceive as proof of its freshness. The sensorial characteristics (look, color, texture, taste, etc.) of the tilapia indicate that it replaces the "cojinova" (*Serioella violacea*) and the "chita" (*Anisostrumus scapularis*).
- The awareness of the origin of the product (reutilization of treated wastewater) has not been a factor impairing consumption. All the same, a proper awareness and publicity strategy could increase significantly the speed of sales and attract new consumers.
- Because of its relative importance among the marketing options, the municipal food markets are the main point of introduction of the product. Some 90% of regular consumers buy fish in those markets. On Saturdays and Sundays up to 55% of the weekly sale of fish takes place. In those days, the rate of replacement of other species with tilapia was 42%, at a sales price of US$1.00 in June 1991.
- The size recommended for marketing was 250 g/fish. It is undoubtedly possible to sell smaller fish without significant loss in terms of relative price.
- The potential demand for Tilapia in the Greater Lima in 1991 would be almost 47,000 MT, and the real demand (by replacement) would be 3,000; 2,200 and 1,300 MT if the prices were 0.80; 1.00 and 1.10 US dollars per kilo. This real demand with the same prices could grow to 4,600; 3,300 and 1,900 MT per year in 2000.

In short, the study showed that tilapia cultivated in treated wastewater constitutes a new food alternative for the Greater Lima market, despite the preference in that region having always been sea fish.

Socio-economic study

The trial allowed designing, dimensioning and funding two commercial tilapia farms adapted to the subtropical (such as Lima) and tropical context, the technical and economic characteristics of which are found in Table 5.35.

Table 5.35: Technical and economic characteristics of the commercial tilapia farms

Parameter	Unit	Subtropical	Tropical
Anual Production	TM	52.8	63.4
Infant period	Months	15	10
Annual	Number	1.0	2.4
Total Área total	ha	16.2	9.0
Water Demand	US$	553,000	673,000
Construction Cost	US$	114,000	76,000
Annual Operational Cost	US$	17,000	16,400
Water Cost	US$/m3	0.0062	0.0042
Production Cost	US$/TM	397.30	306.60
Economic Present Value	US$	12,800	68,200
Financial Present value	US$	46,400	95,200
Economic Internal Rate of Return	%	24.6	45.1

A treatment plant in a subtropical climate receiving a flow of 100 l/s, may deliver approximately 76 l/s of treated water to be used in aquaculture, at US$0.0062/$m^3$. In a tropical context, where the higher temperature increases the efficiency of the system, the cost would be reduced to US$0.0042/$m^3$. The cost of the land was not considered because the convenience of putting arid areas to use was assumed.

When the tilapia production absorbs all the water treatment costs, the production cost per metric ton of fish increases to US$416.20 for a subtropical farm with a capacity for 52.8 MT per year. A 63.4 MT/year tropical farm, on the other hand, would decrease its costs to US$306.60 per metric ton.

Having access to incentive credit lines, the subtropical farm described above would report an Annual Net Current Value (VANE) of US$12,800 and a financial value (VANF) of US$46,400. The tropical farm mentioned could improve the VANE to US$68,200 and the VANF to US$95,200, and also obtain positive VANF values with increased discount rates at 39%, thus proving its high profitability.

The sensitivity analysis determined that the farms can absorb up to 600 and 1,200% of the cost of the treated water, before the VANF becomes negative in the subtropical and tropical contexts, respectively. Similarly, both cases can bear a land cost of up to US$ 0.50 and 1.70/m^2.
Tropical conditions allow the achievement of comparatively better results as opposed to the subtropical context because of the increased ability to absorb costs, resistance to lower market prices and greater profitability.

Latin America discharges about 400 m^3/s of raw wastewater into its rivers and seas. Such discharges, treated in wastewater lagoons, allow the daily recovery of 480,000 MT of hydrogen, 168,000 MT of phosphorous, and 9,400 MT of potassium, essential nutrients in agriculture. The 240 m^3/s corresponding to the tropical zones in the region would allow the development of 70,000 ha for fish farming, that would produce 500,000 MT per year, with a gross value of 400 million dollars. That production would allow the increase in the regional per capita consumption by 3 kilos per year. It would also employ 700 professionals, 260 technicians and 8,400 workers.

The main environmental effect of wastewater treatment is the drastic reduction of the contamination of water bodies, where they are habitually discharged. The recovery of nutrients for agriculture must also be taken into account. The destination of land to agriculture would allow the formation and conservation of soil on arid lands. Finally, such agricultural activities would produce oxygen that would enter the atmosphere, improving the urban environment.

The risk considered would be the contamination of the product, caused by inadequate treatment of the wastewater, amenable to control by maintaining a controlled flow and by depurating the fish.

From the third phase

The computerized model
The results of the second phase allowed a model to size commercial farms in subtropical and tropical zones. The high temperature of the latter allows the breeding period to be reduced to seven months, leading to three harvests per year. With the program it is easy to calculate, for instance, that to achieve a production of 106 tons per year 32 ha are needed in subtropical areas, while in tropical soils 18 ha would be needed, a condition that also lowers production cost. This model also allows an economic assessment. The in case of a tropical farm producing 127 tons per year, with a required yearly investment of US$193,000 and annual operating costs of US$35,000, the cost would be US$0,34/kg. The model also performs sensitivity analysis to study the variation of the profitability in the face of different land and water treatment costs, interest rates, etc. Thus, prices between US$1.00 and 2.00/kg would result in an Internal Rate of Return (IRR) between 35 and 83%, evidencing the high profitability of those projects and allowing them to compete with traditional fishing. This case does not take into account the cost of the land, based on the premise that barren land would be used in urban areas located in arid regions.

Finally, the initial model was considerably changed in 1997, to render its management easy for designers and professionals. A useful model to design tilapia farms at the project profile level was achieved. Its basic context variables are the characteristics of the raw waste and the surface available for treatment, plus the several farming options for the subtropical and tropical contexts. Several premises were determined to simplify user choice. Many processes and calculations were set aside to simplify the selection of choices and obtain a useful report as soon as possible, within a valid and consistent context.

Efficiency of the treatment system
In the period since the completion of the experimental step of the second phase, San Juan has been monitored by means of periodical BOD_5 and fecal coliform measurements, evidencing the quality of the treatment. Only on the occasions in which significant differences in values were found, further parameters such as ammonia nitrogen, phosphorous and phytoplankton were assessed to investigate the reasons for the changes and take corrective action.

After 8 years a special monitoring of 22 parameters was considered convenient to assess whether important changes of the characteristics of the raw wastewater and/or treatment process that could affect the quality of the fish had taken place in that period. Table 5.36 shows the results (average values) of the 16 main physical, chemical and biological parameters measured in the wastewater lagoons in the periods of 1988-90 and 1998.

The comparison of the values from the assessed period shows that the concentration of organic matter (BOD_5) had decreased by 26% as a consequence of larger supply of water in Lima's Southern Cone. Undoubtedly, the soil chemical oxygen demand (COD) decreased by 13%, and that caused the COD/BOD change to 2,4 to 1, while the normal value for household wastewater is 2 to 1, as proved in 1988-90. This new ratio could be the consequence of agroindustrial wastewater input.

Table 5.36 Mean values of the physical, chemical and biological parameters that have been measured in the pond systems from 1988 through 1990 and 1998.

PARAMETER	RAW		PRIMARIES		SECONDARIES		TERTIARY	
	1988-90	1998	1988-90	1998	1988-90	1998	1988-90	1998
COD Total (mg/l)	562	491	202	225	183	156	171	162
BOD_5 total (mg/l)	278	206	53	56	91	48	80	42
TSS (mg/l)	270	232	96	111	111	93	103	93
VSS (mg/l)	229	194	88	96	100	78	94	80
P Total (mg/l)	7.70	8.37	4.73	5.75	4.76	5.30	4.54	4.79
N total (mg/l)	66.8	49.8	30.4	29.7	17.7	19.1	12.4	10.9
N organic (mg/l)	19.3	14.4	8.2	8.7	10.6	8.7	10.6	9.9
N amoniacal (mg/l)	47.5	35.4	22.2	21.0	7.1	10.4	1.8	1.0
Nitrites (mg/l)							0.43	0.89
Nitrates (mg/l)							0.72	1.0
Alkalinity (mg/l)	260	216	210	197	154	153	135	127
Chlorofile A (ug/l)	0	0	943	713	1139	738	1113	727
SAAM (ug/l)		4.8		1.8		0.6		0.5
Total Coliforms (NMP)	1.72E+09	8.05E+07	1.53E+07	1.52E+07	3.40E+05	2.98E+05	2.03E+04	1.54E+04
Vibrio cholerae (NMP)	2.70E+03	1.59E+04	9.20E+00	1.39E+03	8.00E-01	1.06E+02	1.60E-01	1.68E+01
Salmonella (NMP)		6.21E+02		2.48E+02		5.25E+00	4.30E+01	2.75E+00

As a consequence of the lower concentration of organic matter in the raw waste, the fish tanks are also receiving 50% less. Even when the phosphorous and nitrogen levels remain almost the same, a significant decrease of 35% in the primary productivity (chlorophyll) is still observed. The presence of a large biomass of blue-green algae, or cyanobacteria, at the beginning and end of the 1998 assessment period, and that made up 90 to 95% of the existing algae, could explain the reduction in green and flagellated ones that normally make up the phytoplankton. Those blue-green algae concentrate on the surface of the lagoons, limiting the penetration of light to the rest of the water column. Green (*Scenedesmus, Chlorella* and *Ankistrodesmus*) and flagellate algae (*Chlamydomonas*) are still the dominating species as they were 8 years ago; the blue-green alga *Coelosphaerium* has appeared recently, in 1997.

The greater dilution of feces in the raw wastewater mentioned before is also evidenced by the decrease in coli from $10E^9$ to $10E^8$. Despite this lower bacteria load, it has been observed that the system lost some of its efficiency in removing bacteria, since the values of tertiary effluent are similar to those achieved in 1988-90. This loss in efficiency could be related to the lower phytoplankton biomass found in 1998, already discussed. An increased level of *Vibrio cholerae* was also found in the raw wastewater, but this is not very important in the effluent (17 UFC/l). On the other hand, the *Salmonella* concentration in the effluents has been reduced to almost zero.

In addition to the parameters discussed above, concentrations of 37 enteroparasites per liter of raw wastewater, composed of 19 protozoa (18 *Entombed coli* and one *Giardia sp*.) and 18 helminthes (7 *Hymenolepis nana*, 5 *Hymenolepis diminuta* and 6 *Ascaris sp*.) were found. None of those parasites was found in the primary effluents, leading to conclude that a total removal of the parasites is still achieved in the primary lagoons, since they always maintain a retention period of over 10 days.

Similar to the second phase, the concentration of heavy metals like cadmium, chromium, mercury and lead measured in this special control were not significant, and their complete removal was evidenced in the primary lagoons.

As aspect evaluated in the last monitoring was the removal of detergents that represent over 90% of the concentration that enters the system with the raw wastewater. Amounts of 0.5 g of SAAM per liter in the effluent poses no danger to the fish cultivated.

Sanitary conditions of the fish

Microbiological analysis performed in the fish sampled in the breeding tanks between March and May, 1998 evidenced an average concentration of 1,386 heterotrophic bacteria and 10 fecal coliforms per gram of fish. Those values are well below the 10 million heterotrophic bacteria and 400 fecal coliforms considered by the ICMFS as limits for warm water fish. All the same, the values found are also below the values of 5,664 and 408 recorded in 1988-90 for the same parameters, showing that the Unit is currently producing fish with higher quality than at the beginning.

The analysis of cadmium, chromium, mercury and lead showed that there was no accumulation of those heavy metals, since the low concentrations detected in the raw wastewater are completely removed in the treatment process.

Fish production

The continuous distribution pilot program was maintained to serve the local market; to date, over 19,000 kg of tilapia between 250 and 600 g each were marketed for direct human consumption and 340,000 tilapia alevines to be bred in Peru farms. This permanent operation of the Aquaculture Unit has also maintained an important qualification program for professionals, teachers, university students and technicians working in other similar plants.

The investigation program carried out in the last years has led to the results disclosed in table 5.37.

a. Comparative breeding of silver and red tilapia

Though no differences were found in the survival of both kinds, the silver tilapia showed a growth rate 2.44 times higher than the red tilapia. The silver tilapia productivity was also 2.6 times higher, reaching 24 kg/ha/day between 33 and 67 days. Those results could be due to the fact that the silver tilapia is more adapted to natural food, while the red tilapia is brought up only artificial feed only in Panama and Costa Rica.

b. Comparative breeding of silver tilapia from Panama and San Juan

The preliminary results of up to 90 days of breeding show that the Panama tilapia has a growth rate 39% above the one existing in San Juan, possibly because of a better genetic selection of the first and greater consanguinity of the second. The combination of both, though leading to improved growth, does reach the Panamanian rates. In October the survival will be assessed and that trend will be definitively confirmed. Without doubt, the results already lead to believe that the Panama kind would replace the existing one to improve production.

Table 5.37:Results of the comparative breeding of red and silver tilapia in the treated water from the wastewater lagoons of San Juan (from Nov 21, 97 to Apr 6, 98)

Variety	Unit	Red Til.	Grey Til.
Initial Population	No.	1000	1000
Final Population	No.	696	671
Survival	%	69.6	67.1
Initial Density	Fish/m2	1.25	1.25
Final Density	Fish/m2	0.87	0.84
Initial Weight	g/fish	35.13	34.04
Weght 136 days ahead	G/fish	130.6	266.43
Increm. Weight	g/fish	95.48	232.39
Growth rate	g/fish.day	0.7	1.71
Initial Biomass	kg/ha	439	425
Biomass 136 days ahead	kg/ha	1,136	2,235
Increm. Biomass	kg/ha	697	1,809
Productivity	kg/ha.day	5.13	13.3
Results from the comparative breeding of tilapia of San Juan, Panamá and combined with treated water from the San Juan stabilization ponds (from Apr 20 through Jul 20, 1998)			
	Unit	**San Juan**	**Panama**
Initial Weight	g	2.0	1.6
Weigt 90 days Ahead	g	29.6	40.0

Increm. Weight	g	27.6	38.4
Growth Rate.	g/día	0.92	1.28
Biomasa Initial	kg/ha	150	120
Biom. 90 days ahead	kg/ha	2,220	3,000
Increm. Biomass	kg/ha	2,070	2,880
Productivity	kg/ha.día	69.0	96.0

Conclusions and recommendations

Among the main achievements of the study, it may be said that the treatment of wastewater in wastewater ponds is appropriate to obtain effluent with levels of fecal coliforms below 100,000 NMP/100 ml, the quality limit established for the production of fish suitable for direct human consumption.

The fish production system presented encompasses the introduction of a "Nile Tilapia" *Oreochromis niloticus* population at the rate of two 60g fish per square meter. In four months, the system achieves a load capacity of 4,400 kg/ha of 250 g fish and a productivity of 30.8 kg/ha/day, without artificial feed.

The market survey of Tilapia carried out in the Greater Lima evidenced good acceptance of the tilapia, there being no evidence of reservations as to the origin of the product. The potential monthly demand in 1991 was 180 MT at US$1.00 per kilo of tilapia.

The research program carried out in the past years has led to the improvement of the productivity of the system. Thus, it was observed that the common carp (*Cyprinus carpio*) is not as resistant as the tilapia in the conditions of the treated wastewater of San Juan. It was also proved that the red tilapia grows less than the silver tilapia traditionally used in San Juan, and that the introduction of the new variety of tilapia from Panama is showing better growth than the existing variety, therefore it would be replaced to improve production.

CEPIS is currently designing integrated wastewater treatment and utilization units combining different agricultural, aquacultural and forestry elements to diversify the production, improve the efficiency and reduce the investment risks.

Investigation should be continued to optimize the fish breeding systems in treated wastewater, employing other species, assessing the quality of effluent from lagoons other than wastewater lagoons, and the production in other tropical areas. For that purpose, showcase units should be implemented in larger scale and in tropical areas, where a larger productivity is expected. Those units will support a dissemination and qualification program to ensure the repeatability of this alternative technological scheme.

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6. Europe (West)

6.0 Introduction

6.0.1 The countries of Western Europe

The overriding reasons for the division of Europe into East and West were the availability of information and the routes to access it, the current situation and practices, the standards to be met, and the immediate priorities for action. Western Europe includes all State Members of the European Union plus five non-Member countries, viz.: Cyprus, Liechtenstein, Malta, Norway, and Switzerland. The State-Members of the Union make up the bulk of Western Europe. They had a population of 372 million in 1995. With the other 5 countries, the total estimated population by the year 2002 will be about 395 million.

Taking the European Union alone, population density in 1995 was 115 inhabitants/km². There were almost 150 million households, and more than 15 million foreign residents. The Gross Domestic Product (GDP) was 6192 bn ECU in 1994. Some 55% of the population is actively employed, of which 5.5% in agriculture, forestry and fishing; 30.6% in industry, and 63.9% in services. As an average, there are 2.54 person per household, and in 1994, there were more than 150 million automobiles or more than 420 per 1000 inhabitants, more than 45000 km motor ways, and a rail network of more than 150000 km.

6.0.2 The situation at a glance

The region is rich in important river systems some of which are very large. On the Continent, the rivers are often long and fed by many tributaries. Large cities and industries are often located upstream. The most outstanding examples are the Rhine, the Danube, Elbe, and Oder in Germany, the Warta and Vistula in Poland, the Rhone, Garonne, Loire and Seine in France, the Ebro, Duero, the Guadiana and the Taco in Spain, and the Meuse in Belgium and the Netherlands. Several of these rivers cross one or more international borders and call for concerted international action, e.g. the Rhine, Danube, and the Meuse. The water pollution and the consequent effects on water uses downstream are high in most cases.

River systems in England, Italy Norway and Sweden and Finland are comparatively short. The major polluters are often located near their mouth or close to the sea, or on estuaries. Yet, in England and Italy, large polluters are also located in-land.

There are only two sizable lakes in the region, the Lake of Constance and the lake of Geneva. They both receive Alpine water, are about 350 m deep and have moderate flowthrough rates. Both receive a fair load of domestic sewage but limited industrial wastes. The lakes have several riparian states; international coordination for the management of wastewater and stormwater exists. The smaller lakes in Switzerland, Germany and France and most of the other countries are of local and/or sub-regional importance. All pose problems of pollution both domestic and industrial.

Groundwater is considered a special case in Europe. More than in some other regions of the world, groundwater is an important source for public, industrial and agricultural water supply and its protection against pollution is of paramount importance. The high density of population and industry in some of the countries poses important threats to groundwater quality.

Water pollution became a public and political priority in the 1950s and 60s in all of the European countries soon after the reconstruction following World War II was aggressively initiated. The authorities concerned and the operating agencies maintain records and statistical information to the best of their capabilities. Initially, the information was not complete and not of a high reliability, often spotty and not comparable between countries. Nevertheless, the data demonstrated that many people were still not connected to sewerage and that the discharge of the sewage to rivers or lakes was generally unsatisfactory. Perhaps one third of the sewage collected in communal systems was discharged without any treatment. Of the remainder, perhaps half was treated by sedimentation and the rest by biological methods, often trickling filters. Activated sludge treatment was the exception rather than the rule.

The Commission of the European Communities and the former Committee of Mutual Assistance in Eastern Europe promoted improved monitoring and recording of information. But full European cooperation in wastewater management was not possible until the late 1980s. Since then, surveys concerning wastewater management and water pollution control were undertaken as part of comprehensive studies of the European environment, i.e.:

- The so-called Environmental Performance Reports by the OECD and the ECE. They examine the burden and the control of pollution in air, water and other environments, policy and legislation, administration and international cooperation. Fourteen such reports were available as of 1998.
- The so-called "Assessments" of a wide range of environmental conditions, including those of inland waters. The First Assessment was compiled jointly by the European Commission, the ECE, the OECD and WHO, and published in 1995 (EEA 1995). The Second Assessment was published in 1998 by the European Community (EEA 1998); the underlying information was compiled jointly by Eurostat and the newly established European Environment Agency (EEA). The third report was published by the EEA in 1999 and is entitled "Environment in the European Union at the turn of the Century" (EEA, 1999).

From the above review it will be understood that Europe-wide information on wastewater management is gradually becoming "harder" though the information is still variable and incomplete, and in some cases confusing. The Second Assessment referred to above contains information of considerable interest: it shows that the percentage of the population served by wastewater treatment varies from about 50% in the Southern to about 80% in the Northern and Western countries. It concludes that wastewater treatment has improved in many countries during the past 10 to 15 years, especially in the South of Europe where the backlog was large. A larger proportion of the population has been connected to treatment plants and the treatment level has changed. There has been a pronounced change from primary to secondary treatment and with it, a substantial reduction of the organic degradation of European rivers. Moreover, in Western and Northern Europe, the introduction of tertiary treatment, usually with phosphorous removal, has grown substantially in the past decade.

It is also observed in the Second Assessment that in the majority of the European cities, wastewater is still collected together with rainwater and discharged to water bodies and, accordingly, that eutrophication resulting therefrom is particular severe in urban estuaries where the input form cities is large. For instance, the Baltic Sea receives the effluents of more than 70 million people and from their industrial and commercial activities, and is showing increasing signs of stress.

6.0.3 Lessons of the past

Western Europe of the Nineteenth Century was the cradle of today's technology and organizational approach for the management of waste water and stormwater, while, of course, many much earlier examples of sewerage, and stormwater disposal have been recorded as part of the history of the great ancient cultures and city states of the Far and the Middle East and the Mediterranean. Yet, in the case of Europe, it was the combined effect of urbanization, industrialization and enlightened local and central governments which not only called for action but also enabled the planning and implementation of projects of hitherto unknown magnitudes in the terms of the size of the population served, public health purpose, water pollution control and environment protection.

Area-wide drainage systems were introduced in England during the second half of the Nineteenth Century. They became indispensable following the rapidly increasing use of the water flush toilette. They relieved the city of its stormwater and sewage without the nuisances created by the discharge of foul water in open street drains. But they polluted the River Thames and many others of the English rivers. The emerging industries were often built on the shore of the rivers and added their own share to water pollution. British engineers were called to replicate drainage systems in Continental Europe, e.g. Paris, Hamburg, Vienna, and many others. Soon, water pollution became a problem with a European dimension.

In 1858, the Local Government Act prohibited the cities and towns in England to pollute rivers whenever other uses were thus impeded. Only 3 years later, in 1861, the Act was amended to the effect that sewage must be purified if otherwise the quality of rivers was degraded. River Pollution Commissions were established beginning 1868 and 1875. The Rivers Pollution Prevention Act became law. The lesson of these developments in England, the first country to undergo rapid industrialization, stipulates that without a political will and legislation, water pollution from sewage and stormwater cannot be prevented - even today.

Three other lessons emerged from the English experience:
- The most rational method to combat water pollution was the river basin approach.
- New technologies were needed.
- Industrial liquid discharges needed specific attention.

As regards the technology for the purification of sewage and industrial effluents, the English experience is also noteworthy. Soon is was recognized that land disposal of untreated waste water was not to be recommended. The putrescence of the organic matter in sewage and industrial waste was better understood as well as its effects on lagooning and sedimentation. Research with filtration soon pointed to intermittency and than to biological treatment. Efforts were made to study chemical methods for coagulation. Among the most important developments was the research to measure and estimate the pollution load originating from a population, its composition and its environmental effects. Today, this sounds trivial. But before the turn of the Century, and for some time thereafter, this type of information was lacking, and the construction of sewage treatment plants were subject to many uncertainties.

The first steps towards today´s sewage treatment technologies involved the invention of methods, and often machinery, for the removal of grit and settleable solids. Only thereafter, was the digestion and the drying of sewage sludge given the same degree of attention. Many designs were tried, often on a large technical stage. Some of the designs involved structures combining sedimentation in an upper chamber and the anaerobic digestion in a lower chamber. A breakthrough was the invention of the Imhoff tank by Karl Imhoff in 1906, a design adopted throughout the World .

Next on the agenda were filtration, bio-filtration and trickling filters. Chemical coagulation was tried but generally not found satisfactory at the time. In 1914, Lockhett invented the activated sludge process.

During the last 150 years, many things have changed, i.e. the problems, the scientific base, public perception and priorities, the amount money and other resources available for the proper management of waste water and stormwater, the availability of trained personnel, and technology itself and its cost.

There are many other lesson to be learnt from the European experience with respect to the gradual extension of wastewater and stormwater systems from the bigger cities and towns to the smaller communities; the evolution of the environmental standards to be met, especially now that much progress has been made in the reduction of the organic load discharged into rivers after biological treatment of the wastewater; the reconstruction after World War II; the handling of industrial wastes; the best ways of reducing stormwater overflows; the effectiveness and efficiency of treatment technology; standardization; surveillance; and, ultimately, operation and maintenance and the training of the many personnel needed for the planning, implementation and operation of wastewater and stormwater systems.

A unique lesson offered by Western Europe relates to wastewater management in the context of the integration of Europe and the role of the European Union (EU). While perhaps not of immediate and direct application to the developing countries, this lesson is nevertheless relevant in many ways. It is therefore discussed in some detail throughout this Overview.

6.0.4 What is considered the “state of the art” in Western Europe?

The state of the art may be the latest in scientific discovery. However, in European wastewater practice, the state of the art is considered a technology, process and/or an operation which will be best suited to achieve a stated objective in today´s context, e.g. to reduce the BOD of the wastewater to 25 mg/L or by 80%. This implies prior successful testing of the technology in comparison to similar ones. State of the art implies further, that a majority of the experts in the field would accept it as a criterion and that it may undergo changes in accordance with changes as regards the objectives to be achieved, the resources available, and the time frame for action.
Accordingly, in defining the state of the art, the following are considered:

- Comparable technologies, processes and/or operations which have been tested successfully in the recent past.
- Technical advancement and changes in the scientific understanding.
- Economic feasibility.
- Time frame for action.
- Type and quantity of the wastewater discharged.

As will be discussed in Section 6.6, water pollution legislation of the European Union is based on the “best available technology (bat)”. Bat and the state of the art are comparable concepts (Dohmann 1996): on the one hand, the state of the art is the most efficient and advanced technology which is available and practical, whereas, on the other hand, the best available technology is the most efficient and advanced technology which is considered practical to prevent, or, if this should not be possible, to minimize the emission of a pollutant into the environment. Both are not exclusively technical-scientific concepts. In European practice, they include a strong element of practicability and feasibility as measured against the objectives set forth in the water pollution control legislation of the European Union.

It also follows that bat and the state of the art are based not simply on the scientific advancement but rather on the professional judgement of the experts and their professional organizations. It is important, further, that bat and the state of the art represent a majority view of the experts rather than that of an individual scientist or institution. They are not up-dated by continuous process in accordance with scientific progress but rather from time to time whenever one of the four variables has undergone significant change, i.e.:

- The objective to be achieved.
- The scientific and technical understanding.
- The resources available.
- The time frame for action which may be imposed.

Keeping these matters under review and deciding on the timeliness of up-dates is one of the functions of the professional water pollution control organizations which exist in most European countries as well as their Europe-wide professional umbrella the European Water Association (EWA); see also Sections 6.2.1-6.2.2 and addresses in Section 6.10. Their reviews take place in consultation with the regulatory agencies concerned.

6.0.5 Common approaches to the choice of technology

In the developing world, the choice of technology for wastewater and stormwater management is a complicated matter. Many factors need to be considered in addition to the technical ones and the uncertainties are great. In Western Europe, this is more straightforward. On the one hand, there is no longer a dispute over the need and the feasibility of high quality systems for the collection of wastewater and stormwater and for wastewater treatment. On the other hand, uncertainties are minor in comparison with those encountered in the developing countries. Demographic and other developmental information; topographic, hydrological, and environmental data is largely available; and the price elasticity of wastewater and stormwater management is high. Further, there is an overwhelming choice of manufacturer's equipment, maintenance tools, laboratory and monitoring apparatuses, and software for management and operation.

Another feature in the choice of technology in Western Europe is that few projects start from scratch. More often than not, decisions have to be made and technology chosen for extensions and/or the up-grading of existing systems rather than for new ones. In many cases, planners can plan and design on the basis of the performance of existing systems, and their task is then "simply" to extrapolate into the future rather than to consider fundamental alternatives.

Some of the most important factors are briefly discussed below:

- Coverage, degree of treatment, and timeframe: The basic decisions with respect to coverage, degree of treatment, and timeframe have already been taken in the context of EU Directive 91/271 of 1991 (EEC 1991). Communities with more than 2000 pe are targeted to have collection systems by 2000 or 2005 depending on their size. Normally, they must have secondary treatment but in sensitive areas, tertiary treatment is to be provided for communities with more than 10000 pe. Tables 6.12 and 6.13 exhibit the targets and the effluent standards which must be met.
- Separate vs. combined collection systems: Separate systems are generally preferred although they are usually more expensive than combined. Compatibility with existing systems or system components is important. More than half of the collection systems in Europe are combined. As much as 80% of the built up areas may be served by combined systems in some countries, and in practically no case less than 50%. The separation of

combined systems is expensive. Nevertheless, the use of separate systems is likely to be continued, not least for new developments in residential areas provided that safeguards exist to minimize the risk of wrong connections. A major decision criteria is the pollution discharged at times of rain. The above-mentioned EU Directive 91/271 stipulates that the design, construction and maintenance of collection systems shall be undertaken in accordance with the best technical knowledge but not entailing excessive costs. Thus, the choice of technology and system design are governed by environmental and economic requirements, and the intricate task of integrating and/or expanding mixed systems of combined and separate components. The matter of stormwater overflows and their contribution to environmental pollution is discussed in Section 6.2.2.

- Treatment technology: The degree of treatment required has already been discussed above. Within this framework, the choice concerns the processes of secondary and tertiary treatment and the associated costs. These matters are discussed respectively in Sections 6.3.2 and 6.9.
- Industrial wastewater entering urban wastewater systems: Not all industrial waste can be discharged directly into a receiving water. In Western Europe, almost 60% enter urban wastewater collection systems and treatment plants. The municipalities are obliged to receive the waste but authorization is given subject to pre-treatment and charges levied in accordance with the quantity and the quality of the waste. For the State Members of the EU, Council Directive 91/271 stipulates the requirements which industrial wastewater entering an urban collection system and treatment plants shall meet (see Section 6.6.1).
- Cost: The price elasticity of sewer charges is high in Europe. Nevertheless, there are limits to be observed. The matter of cost and cost recovery will be discussed in Section 6.9.
- Economy of scale: The European Waste Water Group (EWWG 1995) observes that wastewater treatment has a substantial economy of scale. The cost per person of a large treatment plant serving 100000 pe is about one fifth compared with that of a small plant serving 2000 pe. It is further observed that a large proportion of the treatment plants necessary in Western Europe will serve relatively small communities; therefore, it will be economical to opt for regional or other forms of joint schemes and/or link small agglomerations to larger systems in the region. In contrast, collecting system do not have the same economy of scale because the length of the network is proportional to the number of properties to be connected.
- Adherence to technical standards: A great variety of norms and technical standards for the collection systems and treatment plants exist in Western Europe. They have been issued by professional associations and/or standard institutions. Some are binding while others are recommended practice. Technology choice in European practice is firmly related to these standards as is best exhibited by the authority accorded to them in the process of giving consent for the construction and/or operation of a sewerage system or a treatment plant. However, it would be overstating the case if this were to imply that the design and/or operation of a system are straight-jacketed by these standards. Nevertheless, technology choice is more governed by standards in Western Europe than would be conceivable in the developing countries of the world. The matter of standardization is discussed in some detail in Sections 6.0.6 and 6.6.1.
- Manufacturer´s choice: The variety of equipment and services offered by European manufacturers and other supplier is a key variable in the choice of technology. The best source of information is the International Trade Fair for Environment and Sanitation (IFAT) which is taking place in Munich every three years and is the largest such gathering world-wide. It covers wastewater, water supply, waste, street cleansing, laboratory technology, monitoring and control, and various types of services. IFAT 12 took place in May 1999 and IFAT 13 is scheduled for May 2002. Subjects covered in 1999 included

sewers pipes and fittings; sewer construction, inspection, monitoring and rehabilitation: pumping and lifting; sewage treatment processes (primary, secondary and tertiary); sludge treatment, stabilization, recycling and disposal; laboratory technology and instrumentation; monitoring and control; energy management and the handling of residues (IFAT 1999).

6.0.6 Technical standards and state of the art reviews elaborated by professional associations

Professional associations exist in most of the countries of Western Europe. At the European level, they are integrated in the former European Water Pollution Control Association (EWPCA) which has been renamed the European Water Association (EWA). They are listed in Section 6.10 and are the most important source of information concerning wastewater and stormwater technology and management in Europe. The national member organizations of EWA comprise more than 40 000 Experts in wastewater and stormwater management as well as many sewage works operational organizations, equipment manufacturers, and regulatory. The Association has a Scientific Committee which keeps a watch on technical and scientific progress and helps evaluate the timeliness of review and the up-dating bat and the state of the art. It is basically at the national level that the professional organizations and national administrations undertake the up-dates and publish them in the languages of their members. It is impossible to present a full account of this work in the present Overview. However below, reference is made to some of the organizations which publish in English, French or German since one of these languages will be understood in most the countries of the region. They are the Association Général des Hygiénistes et Techniciens Municipaux (AGHTM) and the Ministère de l´Aménagement du Territoire et de l´Environnement (MATE) in France, the Chartered Institution of Water and Environmental Management (CIWEM) and the Water Research Centre (WRc) in the UK and the German Water Pollution Control Association (ATV) in Germany.

The AGHTM is a professional centre for the exchange of technical, scientific and administrative information related to all aspects of urban and rural engineering. Further, it promotes studies and research and participates in developing regulations and advisory services. The Association publishes and monthly magazine, and holds a congress and specialized conferences etc. As its name implies, the MATE acts in a combined capacity both governmental and technical which is in line with traditions in France, and is linked with many other organizations in France, including the Office International de l´Eau OIEAU, a non profit association under French Law. MATE convenes conferences and publishes guidelines; OIEAU maintains a sizable documentation service (EAUDOC) and organizes training. CIWEM is strictly technical and publishes introductory books, handbooks and manuals which reflect the state of the art, e.g. handbooks on wastewater practice in the UK (4 volumes) and sewage sludge (4 volumes) Aqualine is a documentation service maintained by the Water Research Center (WRc) which also serves as the Topic Center on Inland Water of the European Environment Agency. The ATV´s publishes a series of handbooks on wastewater practice (6 volumes) and issues Technical Standards and Advisory Leaflets currently covering more than two hundred subjects related to sewerage systems, sewage treatment, sludge, and industrial wastewater; many of these are available in English and an increasing number also in other languages. ATV also maintains a comprehensive training programme at all levels (see also Section 6.7.2).

6.1 Wastewater characteristics (Topic a)

The characteristics of wastewater and stormwater in Europe has been recorded extensively in the literature. EUROSTAT, the Statistical Office of the European Communities is now in the process of assembling additional information from countries with a particular focus on volumes, characteristics and loads, and the degree of treatment. Sources in addition to the domestic sector include agriculture, mining, manufacturing industries (e.g. metals, transport equipment, textiles, paper and paper products, chemicals products and refined petroleum), energy, and construction.

For the domestic (sanitary) sewage, the most convenient source of reference on wastewater characteristics in Europe is Imhoff´s "pocket"-book which is now in its twenty-sixth edition (Imhoff 1985). Imhoff has recorded mean values in Europe since the beginning of the Century and provided generations of European engineers with the basic information they need to study the characteristics of wastewater in a specific circumstance taking into account variations in living conditions, indirect discharges of industrial and commercial wastewater (including cooling water), infiltration of groundwater and discharges of surface water into sewer networks, and both diurnal and seasonal fluctuation. Of course, a basic variable is the amount of water consumed (in households) and the amount of human waste carried away.

As a general guideline, the mean flow of sanitary sewage in Europe is generally assumed to be 200 liters per-capita and day not counting any of the other inflows listed above (Imhoff, 1985). In larger cities, this figure tends to be higher. However, this amount is not used as a design criteria for specific projects it serves as a general guideline but for each individual case, careful measurements and/or an estimation is carried out before a project can be planned.

For the pollution load per-capita and day , mean values for Europe are:

Table 6.1: Pollution load per-capita and day (in g)

Parameter	mineral	organic	total	BOD
Settleable solids	20	30	50	20
Non-settleable solids	5	10	15	10
Dissolved solids	75	50	125	30
Total	100	90	190	60

Source: Imhoff, 1985

Based on an assumed per-capita daily flow of 200 liters, the average strength of sewage in Europe is accordingly:

Table 6.2: Average strength of sewage in Europe (in m/L)

Parameter	mineral	Organic	total	BOD
Settleable solids	100	150	250	100
Non-settleable solids	25	50	50	50
Dissolved solids	375	250	150	150
Total	500	450	950	300

Source: Imhoff, 1985

Other average values have been determined for European conditions with respect of daily peak flows and seasonal fluctuations but are recorded here since they are not intended, nor used, for planning and design. As pointed out before, planning and design are always based on prior study of the quantity and quality of the sewage produced in the given location; the averages quoted above are intended to indicate the likely order of magnitude and guide the specialist in the planning of the study.

Western Europe is one of the most highly and most densely industrialized regions of the world and the variety of industrial wastewater discharged into the environment either directly or indirectly via municipal sewers is very great The quantity and quality of the wastewater is normally expressed per ton of raw material processed or per ton of finished product though are often converted to person equivalents (pe) on the basis of BOD. Variations are very great both as regards quantity and quality depending on the type of industry but also the process applied by each individual enterprise of an industrial sector: variations of between 2 to 5, or even 10 are common.

Table 6.3 exhibits information on the discharges from households and industry. The most representative sample are the so-called EU10 countries which have a population of 333.6 million or 90% of the population of the EU population. They comprise Germany (DE), Spain (ES), France (FR), Greece (GR), Italy (IT), Luxembourg (LU), The Netherlands (NL), Portugal (PT), Finland (FI) and the United Kingdom (UK). Table 5 shows that in the terms of person equivalents, the distribution of wastewater from sewered household and industry is as follows:

- Sewered households: 269.8 million pe or 57.3% of the total load discharged into/via public sewerage systems by households and industry. This represents 36.6% of the total combined domestic and industrial load of 738.4 million pe..
- Industry discharges a total of 468.6 million pe. This represents 63.4% of the combined domestic and industrial load.
- Indirect discharges by industry: 201.5 million pe or 43.7% of the total load discharged into/via public sewerage systems by households and industry.
- Indirect discharges by industry: 267.1 million pe or 43%% of the total load of 468.6 million pe discharged by industry.

Table 6.3: Domestic and industrial discharges in EU10 countries (in million pe)

	DE	ES	FR	GR	IT	LU	NL	PT	FI	UK	EU10	AT*	BE**	DK	IR*	SE*
Total population	81.6	38.5	57	10.5	56.8	0.42	15.4	10.8	5.1	57.5	*333.6*	7.9	10.1	5.1	3.5	8.8
Pop. Connected to sewers	75.2	31.6	29	6.1	46.8	0.415	15	6.2	4	55.5	*269.8*	5.9		4.6	2.4	7.7
% tot. pop.***	92%	82%	51%	58%	82%	99%	97%	57%	78%	97%	*81%*	75%		90%	68%	88%
Pe from industry connected to sewers	47.5	46.6	19.5	2	48	0.2	9	4.7	1.5	22.5	*201.5*			3.9		
% tot. pe	39%	60%	40%	25%	51%	33%	38%	43%	27%	29%	*43%*			46%		
Total pe to sewers	122.7	78.2	48.5	8.1	94.8	0.615	24	10.9	5.5	78	*471.2*			8.5		

* Inhabitants (not person equivalents) - missing industrial discharge. ** no data for Belgium. *** Some of this information is at variance with Table 9 for statistical reasons.
Source: EEA,1999

As referred to above, 43.7% of the industrial wastewater load is discharge indirectly in Western Europe. In Section 6.7.1, some of the requirements are listed which must be met. Of paramount importance is that the public sewers and treatment processes are not damaged by the industrial wastewater. In general, the following need particular attention:

- Temperature.
- pH-value.
- BOD/COD.
- Sludge.
- Ammonium-nitrogen and phosphorus.

- Chemicals, especially lead, cadmium, chromium, copper, nickel, mercury, and the halogenated hydrocarbons.
- Volatile compounds.
- Petroleum products.

EURPSTAT is in the process of collecting information from EU Member States as regards the volumes of wastewater discharged in Western Europe (in m/day) and the load effected by the discharge on the river systems in the region (in 1000 kg/day). This information, which will become available sometime in the near future, will, *inter alia*, include the type of data exhibited in Tables 6.4 and 6.5.

Table 6.4: Information assembled by EUROSTAT on volume (m/day), and organic and nutrient loads (1000 kg/day) discharged by the domestic and industrial sectors (selected items)

Type of discharge	Items recorded
Domestic sector	Volume
Indirect discharges by industry	BOD
Direct discharges by industry	Total nitrogen & phosphorus

As regards industrial wastewater, the discharges of heavy metals shown in Table 6.5 are of particular interest.

Table 6.5: Information assembled by EUROSTAT on heavy metals discharged by industrial sectors in 1000 Kg/day (selected items)

Industrial sectors, e.g.	Heavy metals, e.g.
Mining and quarrying	Cd
Food processing	Cr
Textiles	Cu
Paper & paper products	Hg
Chemical products and refined	Ni
Petroleum	Pb

The effects of the amounts and pollution discharged into the rivers and lakes of Western Europe, and ultimately into the sea have been recorded in the two Assessments referred to in Section 6.0.2, and, more thoroughly, the report on Environment in the European Union at the turn of the Century (EEA 1999). Health effects may be caused where water is abstracted for drinking water supplies from polluted groundwater and surface water, the latter especially along the river Rhine. Polluted beaches in all countries of the region are also responsible for health effects. Effects on agriculture are likely, especially in the South of Western Europe; however, ecological effects are more widespread.

The following are but some of the effects reported by the EEA:

- Organic pollution: From the 1940s onward, the discharge of organic waste has increased but over the past 15 to 30 years, biological treatment of wastewater and radically reduces discharges of oxygen consuming substances from some industries (mainly pulp and paper) have brought down pollution in parts of Europe. Many rivers are now well oxygenated. Information from about 1000 river sites across Europe shows that in mid-1960s, 35% of the sites had an annual average concentration of organic pollution of below 2 mg/L BOD while 11% were heavily polluted with levels greater than 5 mg/L BOD. Now, 6% of the river sites show heavy pollution. In the river Rhine, the concentration of oxygen has increased from an annual average value of around 5 mg/L in the 1970s to current values around 10 mg/L. Figure 6.1 exhibits percent information for rivers with a BOD of more the 5 mg/L, separately for the EU countries in the North, West and South, on the one hand, and, on the other hand, for Eastern Europe. The backlog existing in Eastern Europe is noticeable.

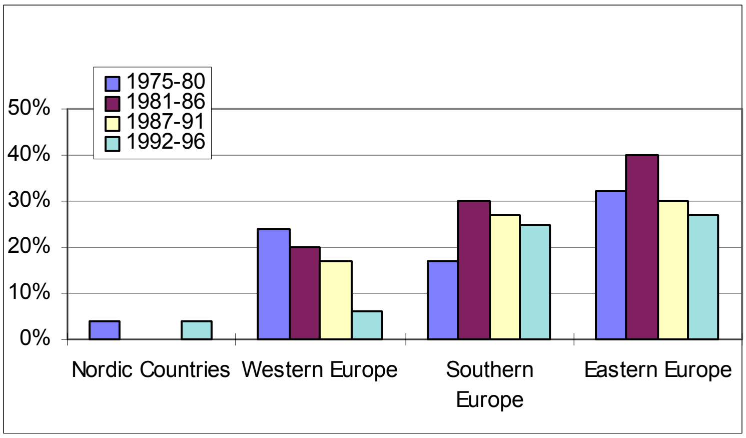

Figure 6.1: Percentage of rivers with a BOD higher than 5 mg/L in the EU (North, West and South) and in Eastern Europe Source: EEA, 1999

- Nitrate: Nitrates are considered a health problem if occurring at levels above 50 mg/L. In EU countries, the Drinking-Water Directive establishes a guide level of 25 mg./L. Actual levels in many private wells used for drinking water supply are above that level (up to around 30%, in some countries). Reductions can only be achieved if the nitrogen load from agriculture is substantially reduced. In European rives, mean nitrate concentrations in 68% river stations exceeded 1 mg/L. There is no overall indication that the reduced application of nitrogen fertilizer has resulted in lower levels in the 1990s. The impact of nitrate is more significant in coastal and marine water than in rivers. There is increased growth of macrophytes and mass occurrence of filamentous algae and phytoplankton leading to oxygen depletion and kills of animal life.
- Phosphorous: Information from about 1000 river stations in Europe shows that 90% had a mean concentration of total phosphorous exceeding 50 μg/L which is more than twice the concentration in waters not affected by human activity. The same situation excists in many of the lakes. Decreases in concentration took place during the 1980s and 90s as a result of improved wastewater treatment and reduced content of phosphorous in detergents but in the future, phosphorous discharges from diffused sources may need to be addressed as well.
- Ecological impact: Oxygen depletion by organic pollution has a strong impact on riverain fauna. After ecological impact has been considerable, improvements have been registered during the past 15 years. Today, most of the countries of the region classify 80% to 95% of the river stretches as having good to fair ecological quality. Rivers with poor or bad quality are generally polluted by wastewater discharges and are in regions of high population density and intensive farming.

6.2 Collection and transfer (Topic b)

6.2.1 Situational overview

According to the European Environment Agency, there has been a dramatic increase in sewers connections in those EU counties where the connection rates were comparatively low. For example in Spain, it has nearly doubled over the past 15 years (EEA,1999). In Section 6.6.1 and Table 6.12, the programme for closing the gap and the financial implications are reviewed: in accordance with EU Directive 91/271, collection systems shall be provided at the latest by December 2000 for agglomerations with a population (pe) of more than 15000, and, at the latest by 31 December 2005 for those with a pe of between 2000 and 15000 (see Section 6.6.1).

More than half of the collection systems in Europe are combined. As much as 80% of the built up areas may be served by combined systems in some countries, and in practically no case, less than 50%. Table 6.6 exhibits the status of wastewater collection in EU Member States.

Table 6.6: Wastewater collection systems in EU Member States (approximate position in 1994)

Country	%-age of population served	%-age of urban areas served by combined systems (estimated)	Age profile of collection systems (where known)
Belgium	58	70	
Denmark	94	45-50	50% after 1960 20% after 1980
France	74	70-80	
Germany	90	67	74% after 1945 60% after 1963
Greece	45	20	60% after 1970
Ireland	67	60-80	
Italy	82	60-70	40% after1965
Luxembourg	96	80-90	50% after 1965
Netherlands	97	74	50% after 1955
Portugal	62	40-50	70% after 1960
Spain	82	70	
United Kingdom	96	70	50% after 1945

Source: European Waste Water Group, May 1995

In its report of 1995, the European Waste Water Group also provides summary information on the length of collection systems in the countries studies. While there are many variation, The report indicates that the average length of public collection system in Western Europe typically falls within the following ranges (see Table 6.7):

Table 6.7: Length of sewer systems in Western Europe

Cities	1.5 to 3 m per habitant
Towns	2.5 to 5 m per habitant
Small towns and Villages	4 to 6 m per inhabitant
Rural areas	more than 6 m per inhabitant

Source : European Waste Water Group 1995

The survey also produced information on the capital cost of providing new collection systems. The following are indicative ranges: as an average for a drainage area with a population of 10000; systems cost between 300 and 375 ECU per meter in established urban areas, and between 25 and 200 ECU per meter in open ground.

Directive 91/271 of the EU Council further stipulates that the design, construction and maintenance of collection systems shall be undertaken in accordance with the best technical knowledge not entailing excessive costs, notably regarding:

- Volume and characteristics of the urban wastewater.
- Prevention of leaks.

- Limitation of pollution of receiving waters due to stormwater overflows.

This implies that costs, the prevention of leaks and the control of pollution from stormwater overflows are given overall importance in the choice of technology, and that compatibility with existing systems or system components is important whenever extensions are planned.

Today, separate systems are generally preferred although they are usually more expensive than combined. The separation of existing combined systems is also very expensive and is often impossible to implement; also the benefit of the investment made for such separations has been shown uncertain in the case of some European cities. The problem is plaguing many of the Northern European countries where rainfall is higher than in the South.

The choice of technology and system design are governed by environmental and economic requirement. The integration and/or expansion of systems comprising both combined and separate components is intricate and involves consideration of:

- The associated operational and environmental implications.
- Rehabilitation of existing systems.
- Compliance with water quality requirements.

New collection systems or additions to existing ones are likely to be combined and they are considered the most economic and practical solution provided their design is responsive to the need to avoid gross water pollution at times of rain.

6.2.2 Priority issue: stormwater overflow

The high proportion of combined sewers reported above is part of the historical development of sewerage in Europe, and is the major reason for a high degree of water pollution originating from combined sewer overflow (CSO). At times of rain, stormwater overflow form combined systems contributes up to 50% of the organic load reaching rivers in Europe, especially now that a high degree of wastewater treatment has been achieved at dry weather flow.

Rainfall in Northern Europe is high though peak rains are the exception rather than the rule. Thus, combined overflows run for long periods of time compared with the tropical countries and countries in the South of Europe and, consequently, the amount of pollution discharged into the environment via overflows is relatively great.

In the past, combined overflows have been tolerated because water pollution was generally high. Today, a high degree of sewage treatment has been achieved in Europe at dry weather flow. It follows that the organic load carried into receiving waters at time of rain may be as high as 50% of the total according to some estimate. Half of this amount stems from combined overflows, the other half form other sources e.g. drainage from roads, industrial and residential areas which must be added to the pollution discharged via the overflows. These discharges are often thought of being clean but in reality contain pollutants originating from many types of surfaces, streets, yards, parking places, especially oil, organic matter, fallout from atmospheric pollution, and toxic metals, and debris deposited in pipes at dry weather. Separate stormwater drains also carry the organic and non-organic load discharged into them via illegal connections. A survey of the causes of poor river water quality in Scotland in 1955 found that 20% of the pollution load reaching rivers resulted from these types of runoff from urban areas (SEPA 1997). New ways of thinking about wastewater and stormwater in urban areas are emerging. They aim at an integrated approach comprising all different sources, the collection and transfer systems, treatment plants and the receiving body of water itself and addressing both water quantity and quality and the use of simulation techniques (A.H. Dirkzwager 1997 & S.P. de Jong *et al.* 1998).

Three basically different approaches are used to control water pollution from CSO:

- Source control: Retention at the source by temporary storage of rainwater and gradual release; infiltration or seepage of the rainwater into the ground via tanks or channels, or porous pavements of parkings etc.; the reuse of rainwater; ponding in artificial wetlands; or reuse in urban beautification (e.g. recreational ponds etc.). In contrast to the measures listed in the subsequent paragraph, those referred to here are often ignored by the organizations responsible for the management of the systems, partly because they may be cumbersome to plan, implement and manage and, thus, do not lend themselves to a centralized approach.
- Improved management: Better operation and maintenance of inlets, pipes and all other structures of the sewerage system; the prevention of solids entering; control of illegal connections; the redesign and/or improved operation of intended overflow structures and unintended other overflows with particular attention to frequency and volume of the overflows; the storage of peak flows, and, last but not least; the in-line retention of peak flow. Books have been written about most of the measures referred to here, especially the provision of stormwater retention tanks and their planning, design and operation.
- Separation: Theoretically at least, separation of combined systems into sanitary sewers and stormwater drains would appear to be an ideal solution. However, this option is of limited use (see below).

In its report of 1995, The European Waste Water Group concluded that the key factors crucial for the design and management of collecting systems, consistent with meeting both environmental and economic requirements, are:

- Clearly defined long-term quality objectives for the receiving water which must include parameters of particular relevance to CSO.
- Reliable and detailed information regarding the wastewater collection and treatment system and a good understanding of stormwater and CSO impact in the individual receiving water.
- A planed phased programme for improvements which cannot be designed without appropriate analytical procedures and modeling tolls for the assessment of the improvement options consistent with meeting the needs of the receiving water.

From the analysis of the situation in EU Member countries the Group recognizes that advantages and disadvantages are associated with both combined and separate systems. The latter are still generally preferred for new developments in Europe, more particularly residential areas although they are expensive. Obviously, nutrient discharges from separate systems are generally lower than those from combined systems but they often have higher loads of metals and hydrocarbons. Also, separate systems always involve the risk of cross connections and illegal connections many of which are difficult to locate and control. But in spite of the current preference, logic commands that the separation of existing combined systems in Europe is very costly and generally impractical. Often, a separation offers but limited benefits. This implies that in Europe combined systems are there to stay. Thus, the improvements measures indicated above must be adopted and their feasibility, timing and introduction investigated. In this process, some of the traditional approaches have undergone change:

- Stormwater overflows have traditionally been based on a dilution ratio expressed as a multiple of dry weather flow (between 2 to 10 with a common value of between 3 and 8).

- Design criteria have been based on the needs of the collection system with mainly economic reasons in mind. Now the needs of the receiving waters come to the fore and, thus, surface water quality criteria will be the decisive parameters such as those included the forthcoming EU Directive on Waster Policy (see Section 6.6.1).
- Many of the overflow structures and other network features have been designed by criteria longer applicable. New criteria are being tested.
- As sewage treatment processes become more advanced, both the hydraulic and pollution load imposed at times of rain will be more important than in the past.

The financial implications of CSO improvements are very large. Careful planning of the remedial measures and long-term solutions are given a great deal of attention. An integrated approach to panning and management of catchment areas is adopted. A project is underway funded by the EU´s Innovation Programme which combines some of the existing computer programmes (viz.: MOUSE, MIKE and HYSTEM-EXTRAM) into modeling tools for urban catchment covering rainfall, sewers and sewage treatment works, and the receiving water. The project also aims at the development of common European standards for integrated catchment management. 16 partners from six EU countries, the Water Research center of the UK, the Danish Hydraulic Institute, and the Swedish Water and Wastewater Association participate in the research (R. Crabtree et.al 1998). An example is exhibited in Case Study 1 (Section 6.11.1).

The Planning Guide for Urban Pollution Management (UPM) of the Foundation of Water Research (FWR) of the UK is another tool (FWR 1998). It is now in its second edition and available on CD ROM. The information presented in the following paragraphs is excerpted from UPM and outlines the four phases of the Guide´s Planning Procedure (see also Figure 6.2):

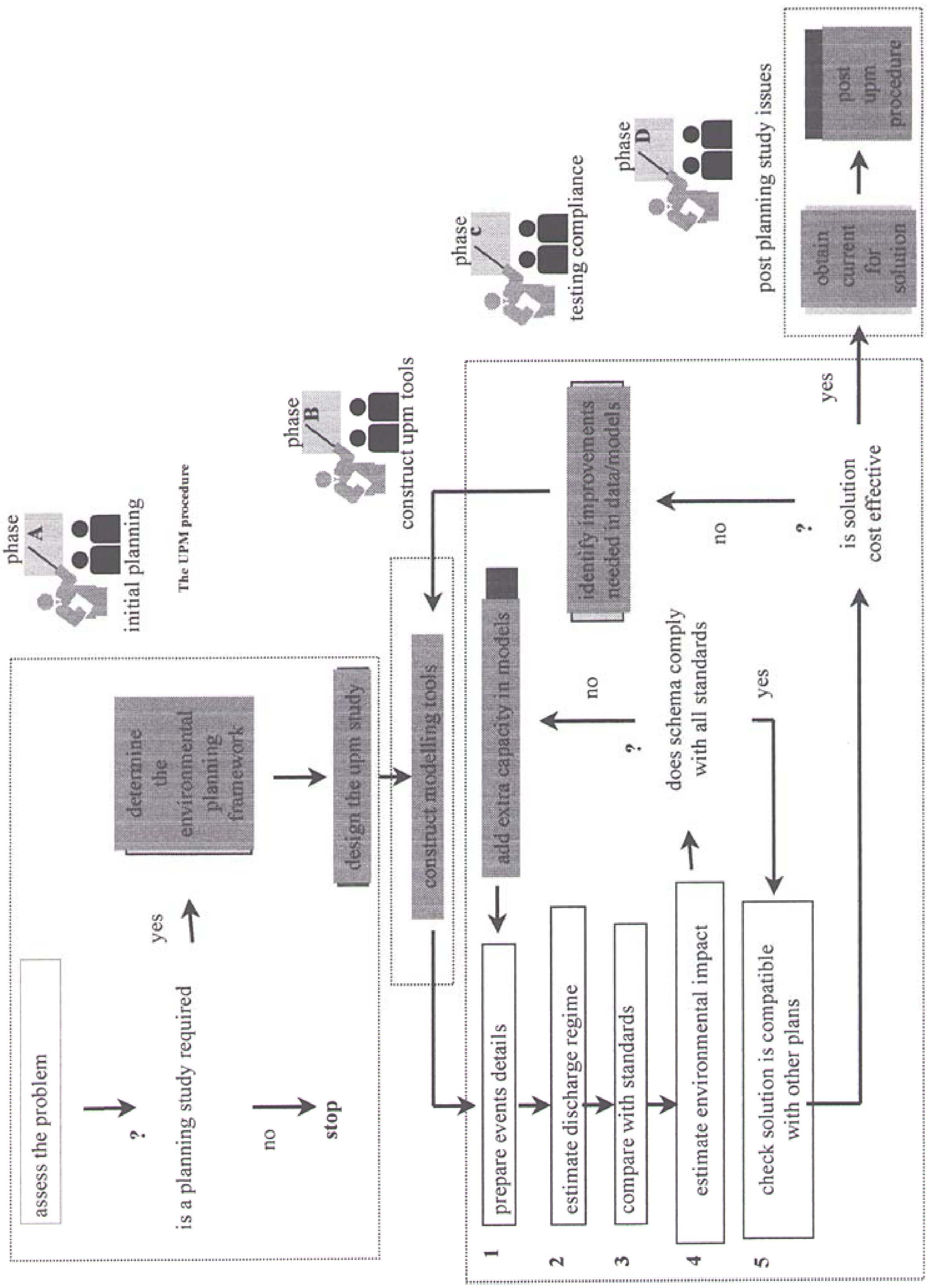

Figure 6.2: The UPM procedure

Source: FWR, 1998

- Phase A: The best possible understanding of the current performance of the system is obtained on the basis of existing information. At the end of this phase, agreement is reached, including on the standards applicable, viz for aquatic life, bathing or general amenities. The full course of the investigation is planned and judgements made on the relative importance of different discharges and water quality interactions.
- Phase B: The data and models to be used in the investigation are assembled and the models are adjusted by appropriate processes of calibration and verification. The work involved can vary enormously depending on the form of the study. Modeling may extend to rainfall, sewer flow and quality, STP quality, river impact, estuary impact, marine impact, and, finally, integrated urban pollution.
- Phase C: The models developed during phase B are used to study the performance of the existing system vis-a-vis the standards. Proposed upgrading solutions can be incorporated and the degree of improvement identified. This may involve iteration.
- Phase D: Phase D covers discharge consent and engineering design. The latter deal with CSO structures, detention tanks, source control, sewer system transport capacity, and STP performance. Post project appraisal will be undertaken and the measures needed to maintain the model and database for future use are identified.

There are extensive appendices and a software SIMPOL developed to facilitate implementation of the UPM procedure, and there is also an Annex with worked examples. The important concept of the Manual is to consider the system comprising the sewers, the treatment plant and the receiving water as a single entity which is underpinned by environmental standards. The Guide is applicable throughout Europe and written in a generic manner without reference to specific software in recognition of the wide range of software packages now available to users.

6.3 Treatment (Topic c)

6.3.1 On-site systems

It follows from Table 6.6 that with the exception of few countries in Western Europe (e.g. Greece, Ireland and Spain), most people are connected to sewerage systems. Yet, on-site systems still exist in all countries to some degree. However, in contrast to many developing countries, the population served by on-site systems is basically rural or isolated; on-site systems in the “urban fringe” are the exception rather than the rule and will disappear after the EU´s Directive 91/271 has been implemented (see Section 6.6.1).

After World War II, permits to built a dwelling were made depended on the existence of either on-site or off-site disposal of the wastewater. Where an on-site system is appropriate, the requirement is in most cases for a septic tank. Yet, other systems are in use in older dwellings and isolated places: pit privies and latrines of various types. There are also several types of package plants on the market for both individual buildings, neighborhoods, and smaller establishments, e.g. hotels, and camp-sites (IFAT 1999).

Most septic tanks are prefabricated. Mostly, they have two compartments and are followed by filtration of the effluent into the ground. When desludging is foreseen (twice yearly) they may have a capacity of 300 L/person and their minimum size should not be less than 3000 L. Without desludging, their capacity may be as high as 1500 L/person (Imhoff 1985). A typical design in shown in Figure 6.3. Infiltration systems use clay or PVC piping of 10 mm diameter laid in a trench filled with gravel or crushed stone. They should have a gradient of 1:400 to 1:500 and between trenches there should be a space of 2 to 3 m. Surface loads are between 10 m/person in sandy soil or gravel to 20 m/person in sandy clays (Imhoff 1985).

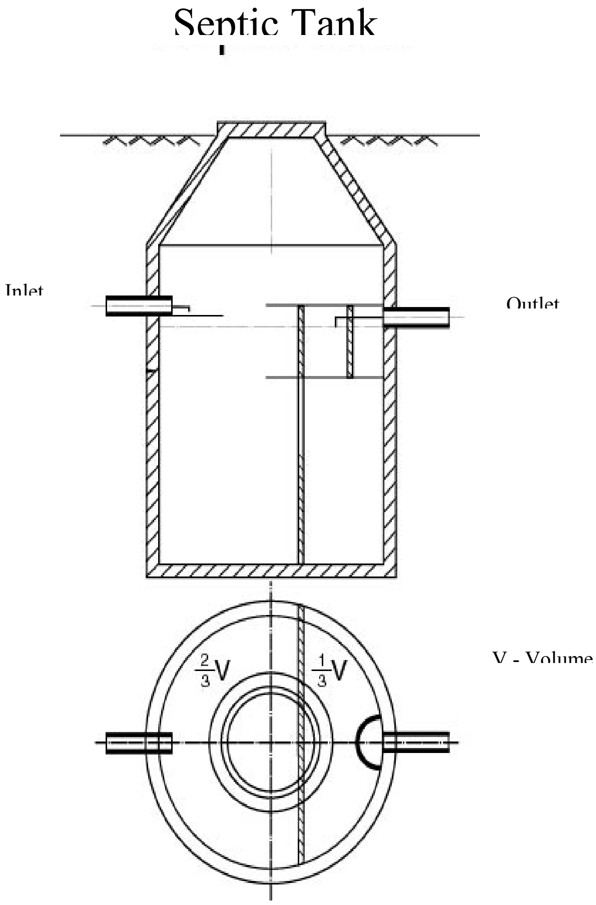

Figure 6.3: Typical design of septic tank

Source: DIN, 1991

Some of the national standards organizations have issued norms for septic tanks but these are superseded by the new norm elaborated by the European Standard Organization (CEN). As will be outlined in Section 6.6.1, five norms will be forthcoming for wastewater treatment for less than 50 pe. They are:

- EN 12566-1: Prefabricated septic tanks.
- EN 12566-2: Soil infiltration systems:
- EN 12566-3: Packaged and/or site assembled domestic wastewater treatment plants.
- EN 12566-4: Septic tanks built in situ from prefabricated kits.
- EN 12566-5: Filtration systems (including sand filters).

EN 12566-1 is already available in draft and should be published soon. The four other norms will follow. EN 12566-1 specifies the requirements for prefabricated septic tanks and ancillary equipment used for the partial treatment of domestic wastewater for a population of less than 50 persons. Pipe sizes, loads, watertightness, marking and quality control are specified.

It should be noted that these norm are not design standards but rather product norms with the aim of contributing to the elimination of trade barriers (which was one of the initial main objectives of the EU), to give orientation to manufactures, purchasers, public tenders and planers, and to give orientation to meet legislative requirements as regards, safety, health and environmental protection, among others. As regards design, EN 12566-1 merely states that depending on the end use, one or more of the following criteria may need to be stated (by the manufacturer):

- Population; total load.
- Minimum sizing criteria including sludge storage capacity.
- Additional sizing criteria for domestic wastewater flows from sources such as hotels, restaurants or commercial premises.

6.3.2 Off-site systems

Overview and future development

The recent report of the EEA shows that the percentage of the population served by wastewater treatment varies from about 50% in the Southern to about 80% in the Northern and Western countries (EEA, 1999). It concludes that wastewater treatment has improved in many countries during the past 10 to 15 years, especially in the South of Europe where the backlog was large. A larger proportion of the population has been connected to treatment plants and the treatment level has changed. There has been a pronounced change from primary to secondary treatment and with it, a substantial reduction of the organic degradation of European rivers. Moreover, in Western and Northern Europe, the introduction of tertiary treatment, usually with phosphorous removal, has grown substantially in the past decade.

Table 6.8 and Figure 6.4 show that treatment is most advanced in the North of the region with 57% tertiary and another 23% biological treatment achieved. Tertiary treatment is found in the Nordic countries, Germany, Switzerland, Austria and the Netherlands, while most of the wastewater in the Unite Kingdom and Luxembourg is treated in plants with secondary treatment (EEA, 1999). In the south of the region, 29% is still discharged without treatment and only 43% receive secondary treatment. In France and Italy, more than half of the wastewater is treated in secondary plants. Over the past 15 years, reductions of 50% to 80% in organic matter discharged and 60% to 80% in phosphorous have been observed in the Northern EU countries but only small a reduction in nitrogen has been achieved; few countries have yet upgraded their wastewater treatment to include nitrogen removal.

Table 6.8: Wastewater treatment of the combined load from household and indirect industrial discharges in EU10 countries (in pe as of end 1994)

	DE	ES	FR	GR	IT	LU	NL	PT	FI	UK	EU10	*% EU10*
Rural population*	5.5	6.9	28	4.4	10	0.005	0.4	4.6	1.1	2.6	63.5	*12%*
Untreated	2.5	43.6	2	2.7	28.8	0.06	0.1	7.4	0	13	100.2	*19%*
Primary	8.3	3.5	4.5	2.7	7	0.03	0.2	1	0.7	13	40.9	*8%*
Secondary	7.3	30.4	41	0.7	53	0.48	5.7	2.3	0	43	183.9	*34%*
P+S+nutrient removal	104.6	0.7	1	1.8	6	0.05	18	0.2	4.8	9	146.2	*27%*
Total	122.7	78.2	48.5	7.9	94.8	0.62	24	10.9	5.5	78	534.7	*% 100*

* Rural populations not sewered
Source: EEA, 1999; European Waste Water Group (1997).

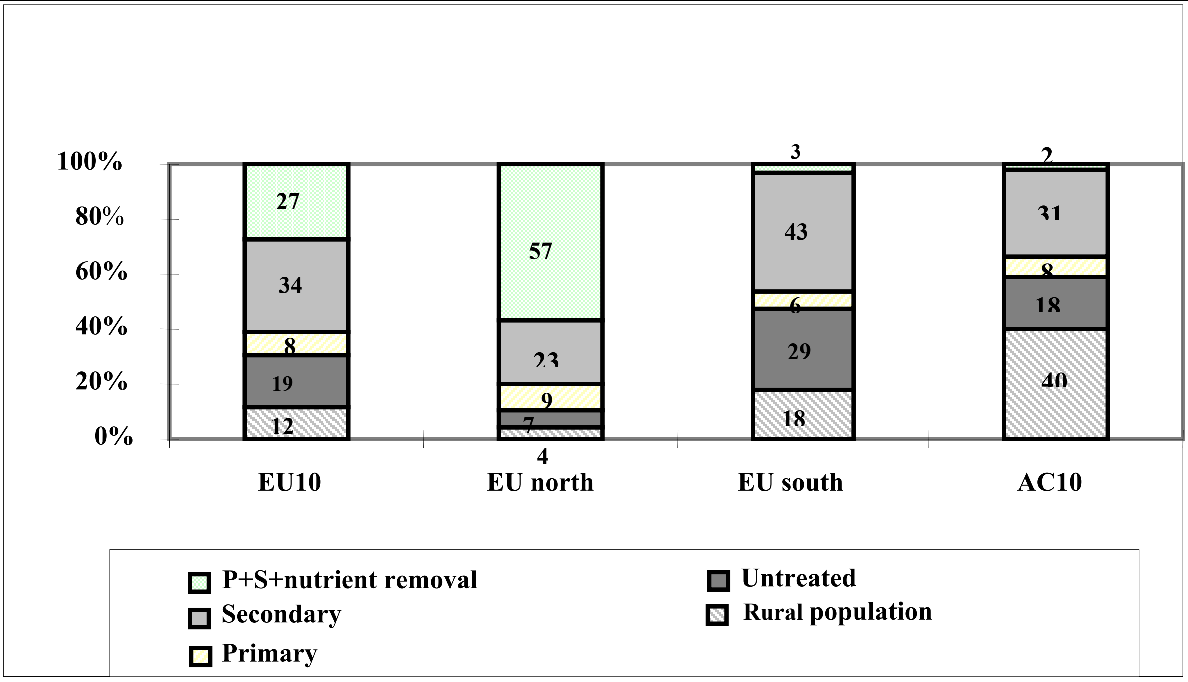

Figure 6.4: Wastewater treatment of the combined load from households and indirect industrial discharges in EU10 Member States

Source: EEA, 1999

Table 6.9 contains information on the percentage of the population connected to wastewater treatment plants on a country-by-country basis. Unfortunately, the Table is not complete and to some degree at variance with Table 6.8. Nevertheless, it is shown here because of the evolution it exhibits between 1990 and 1995 in terms of population percentages. However, of greater interest is Table 6.8 because it is more detailed, more up-to-date and exhibits information with respect to the combined load from both households and indirect industrial discharges.

Table 6.8: Wastewater treatment of the combined load from household and indirect industrial discharges in EU10 countries (in pe as of end 1994)

	DE	ES	FR	GR	IT	LU	NL	PT	FI	UK	EU10	*% EU10*
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Primary	8.3	3.5	4.5	2.7	7	0.03	0.2	1	0.7	13	40.9	*8%*
Secondary	7.3	30.4	41	0.7	53	0.48	5.7	2.3	0	43	183.9	*34%*
P+S+nutrient removal	104.6	0.7	1	1.8	6	0.05	18	0.2	4.8	9	146.2	*27%*
Total	122.7	78.2	48.5	7.9	94.8	0.62	24	10.9	5.5	78	534.7	*% 100*

* Rural populations not sewered

Source: EEA, 1999; European Waste Water Group (1997).

Table 6.9: Population connected to sewage treatment plants in Western Europe (population percentages)

Country	% population connected		At least secondary treatment	
	1990	1995	1990	1995
Austria	72.0	75.7	67.0	73.3
Belgium				
Denmark	98.0	99.0	90.0	
Finland	76.0	77.0	76.1	77.0
France	68.3	77.0	58.0	
Germany	85.5	89.0	79.7	
Greece	11.4	34.0		
Iceland	2.0	4.0		
Ireland	44.0	45.0	21.0	
Italy	60.7			
Luxembourg	90.4	87.5	71.1	68.4
Netherlands	93.0	96.0	92.0	96.0
Norway	57.0	67.0	44.0	52.0
Portugal	20.9		11.5	
Spain	48.0	48.3	41.9	37.7
Sweden	94.0	95.0	94.0	
Switzerland	90.0	94.0	90.0	94.0
United Kingdom	87.0	86.0	79.0	78.0

Source: EEA, 1998

The further development of wastewater treatment in Western Europe is governed by EU Directive 91/271. The Directive and the progress expected are reviewed in Section 6.6.1, Table 6.15 and Figure 6.9.

Priority issue: nitrogen and phosphorus removal

The stringent requirements set forth in the European Council´s Directive 91/271 concerning the collection, treatment and disposal of urban wastewater imply that in the so-called "sensitive" areas of Western Europe a very high degree of treatment must be provided whenever the Population equivalent is greater than 10000 pe (see Section 6.6.1). Figure 6.8 exhibits the extent of the "sensitive" areas. The Directive stipulates that in these areas the concentrations of total nitrogen and total phosphorus in effluent must be extremely low: total phosphorus must be 2 and 1 mg/L, and total nitrogen 15 and 10 mg/L in the effluent from locations with, respectively, between 10000 and 100000 pe and with more than 100000 pe. Percentage reduction rates for phosphorus must be 80% and for nitrogen 70 to 80%. BOD5 and COD must be, 25 and 125 mg/L, respectively, with a minimum percentage reduction of 70-90% and 75%, respectively. Total solids must be below 35 mg/L with a reduction rate of 90%. This implies that in Western Europe tertiary (or advanced) sewage treatment is more common than in other parts of the world. The terms tertiary and advanced treatment are not always used consistently. No comprehensive comparative survey has been undertaken as to the type, processes, design, equipment, and operation of the facilities for advanced treatment in the countries of the EU but a great deal of technical information has been published and is conveniently summarized some of the handbooks referred to in Section 6.0.6 (e.g. CIWEM 1994 & ATV 1997a)

The work horse for advanced treatment is the activated sludge process but trickling filters, rotating biological contactors and fixed bed reactors are also in use either because they exist or as a final stage. Phosphorus removal is usually combined with denitrification and almost always depends on chemical action though in some cases biological processes are used. In the design of the process, the method for the removal of phosphorus is decided first. The methods used are either precipitation prior to sedimentation, or precipitation simultaneously with nitrogen during removal by the activated sludge process, or thereafter. Floculants most commonly used include chlorites, chlorosulfates and sulfates of iron, aluminum sulfate, poly-aluminum chlorite, sodium aluminate, or a mixture of these.

Activated sludge units operate in one or two stages. This is depicted in Figure 6.5. Several options are in use. Nitrification always occurs in the aerobic zone. Denitrification takes place before nitrification in single stage plants, or between two aerobic stages in the two stage process. In the latter case, external carbon sources may be added such as acetates, alcohols, or starches, or either industrial effluent rich in these substances or in internal carbon source like hydrolyzed sludge. There are also schemes which provide for simultaneous denitrification. In these cases, surface aerators create aerobic conditions close to their operating points but when the water flows away from the aerators, oxygen depletion occurs and denitrification can take place. A case study is contained in Section 6.11.2 with further details.

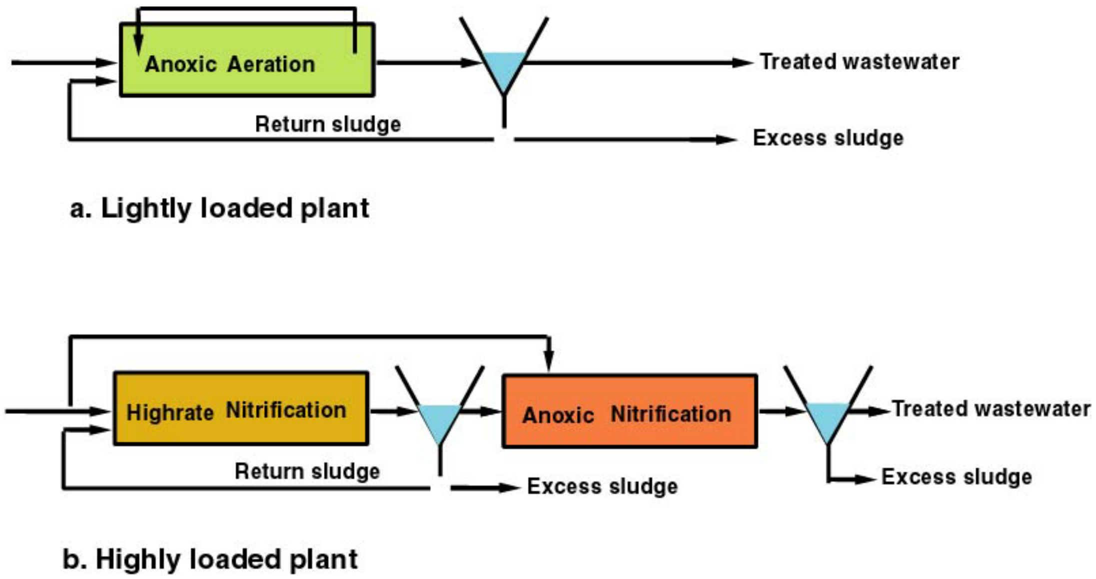

Figure 6.5: Removal of nitrogen

Source: ATV, 1997

Satisfactory results cannot be obtained unless the system is carefully monitored and controlled (ATV 1997b). In the North of Europe, temperature is an important factor; it may be 10 degree Celsius and lower. Parameters to be monitored include, in addition to inflow, detention period, outflow, the amount and the age of sludge: pH and temperature, the organic and nutrient load in the system and its units both in the liquid and sludge phase, recirculation rates of liquid and sludge, and the secondary sludge produced. Effective monitoring is assured by on-line monitors for BOD, COD, TC, ammonia and nitrites and nitrates, and phosphorus and the physical parameters indicated. Automatic systems for monitoring and control are available.

Distribution of the methods used for advanced treatment is not even throughout Europe, nor is the compliance effluent with the effluent standards contained in EU Directive 91/271 concerning nitrogen and phosphorus met uniformly. As indicated in Figure 6.4, there are more plants in the West than East, and also more in the North than the South. In the North and some parts of Germany and in Switzerland, there was a boom in the introduction of nutrient removal during the late 1980s and early 1990s. The protection of some of the costal waters was a motivating factor in such countries like Denmark and The Netherlands where nutrient removal is almost universal. But as a whole, the countries of the EU are probably leading in nutrient removal world-wide.

One of the few comparative studies (Fink et al. 1998) conducted in 6 EU countries shows that plants are more generously designed in countries like Denmark where aeration and secondary sedimentation tanks are larger than elsewhere (540 L/pe). Temperature and higher effluent standards are among the reasons, but also that in Denmark, like in France, plants are laid out for aerobic stabilization, even for up to 300 000 pe. In France, loads are high and with 205 L/pe, aeration tanks small. Small aeration tank are also found in Switzerland and Italy where they have been designed for lower rates of nitrogen removal. There are also differences as regards secondary sedimentation. In France and Italy, the tanks are smaller than in Germany whereas the surface load is the same.

Low loads on the activated sludge process produce removal rates of nearly 90% of total nitrogen in Denmark, France, Germany and The Netherlands. The load may be between 0.044 to 0.064 kg/d in the plants surveyed in the sample. In Italy and Switzerland, the loads of the plants surveyed are higher and removal rates are between 60 and 70%. Phosphorus removal rates are as high as 93% in the plants surveyed in Denmark and The Netherlands, while as low as 70% in some of the other countries.

Case Study 2 (see Section 6.11.2) describes nutrient removal in the wastewater treatment plant Zuerich-Werdhoelzli, Switzerland.

Priority issue: Sludge stabilization and utilization

Sludge stabilization and utilization is a priority issue in Western Europe because of the high degree of sewage treatment achieved aggravated by high population densities, scarcity of land and rigid legislation for safeguarding human health and the environment against hazards arising from waste material. The state of the art is summarized in some of the handbooks referred to in Section 6.0.6 (e.g. CIWEM 1995a and b, 1996 and 1999 & ATV 1997).

Technology development was dominated to large measure by changes in industrial technology, equipment and machinery rather than traditional wastewater engineering. Accordingly, technology is highly sophisticated, bounded by technological inventions and patents, and, increasingly, combined into integrated packages offered by manufacturers. The leeway which planners and consulting organizations usually have in the field of wastewater engineering is limited when technology for sludge stabilization and handling is chosen.

The ultimate disposal of sewage sludge is a key technical and regulatory problem. Where will it end up? And in which form?

Figure 6.6 is an answer with respect to the first of these two questions; the second answer is more complex. The Figure shows the trend and forecast in the then 12 Member States of EU in 1995. Over the span of 20 years, the total amount of sludge will almost double. There is an upward trend in the use of sludge in agriculture, a definite downward trend in sludge deposition and an upward trend in incineration. As of 2005, the estimated percentage of sludge used will be 45% whereas 38% will be incinerated and only 17% deposited (dumped).

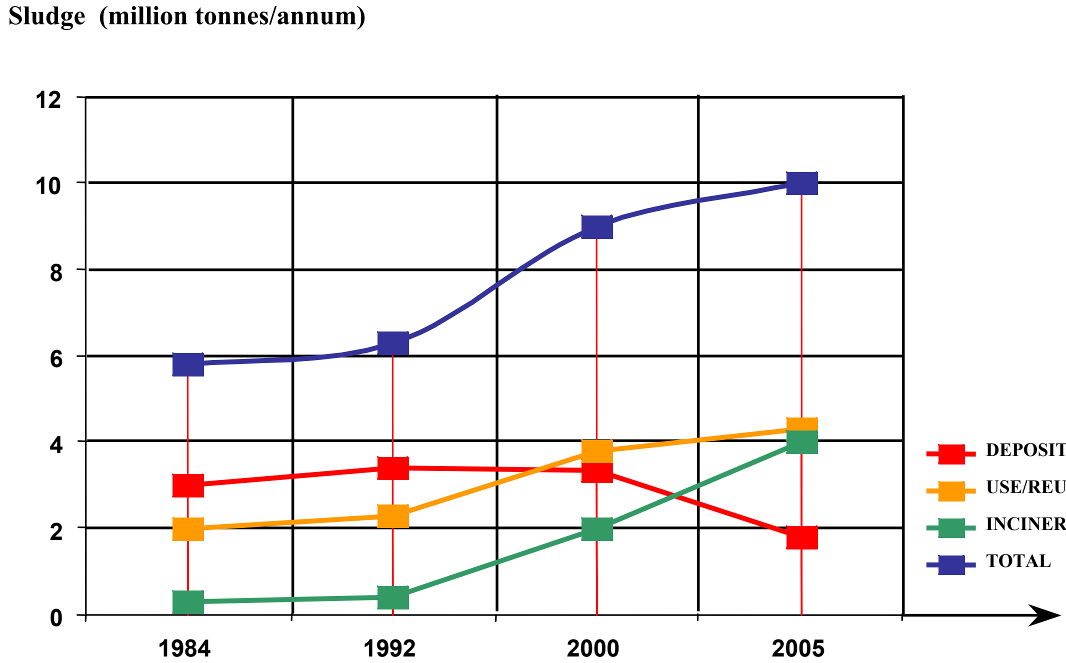

Figure 6.6: Sludge disposal in 12 EU countries

Source: ATV, 1996

The percentages vary considerably between the counties. The but limited comparative study referred to above in "Priority issue: nitrogen and phosphorus removal" provides some insight (Fink et al. 1998). Use in agriculture was highest in France with 58% and lowest in The Netherlands (26%) and Germany (27%). Incineration highest in Switzerland (25%) and Denmark (25%) and lowest in Germany (14%). Deposition is highest in Germany (54%), Italy (55%) and The Netherlands (51%) and lowest in Denmark (20%). The trend in agricultural use is of particular interest: in Denmark it increased by 80% from 1987 to 1990 and in Germany by 50% while it decreased in The Netherlands. In considering the use of sludge in agriculture, methods of composting are given considerable attention in Europe. This will be discussed below. It must also be understood that disposal into the sea will soon end by international agreement.

As regards the agricultural use of the sludge, and the concentration of the hazardous material it may contain, Directive 86/278 of the EU on the use of sludge in agriculture and the protection of the environment and of soil (EEC 1986) sets forth minimum requirements only because prior practice in the countries was very much differentiated. It is based on the maximum permissible concentration of certain metals in the soil; once the concentrations shown in Table 6.10 have been reached, no more sludge may be used on the land. The values for chromium have not yet been agreed upon, and the allowable annual tonnage is not yet included. In some countries, values are more stringent while others have made use of their prerogative to set standards at a lower level. In some countries, additional substances have been added to the list, e.g. arsenic, fluorides, molybdenum and selenium in the UK, parts of Austria, and Switzerland. Germany has added limits for dioxins, PCBs and AOX.

Not contained in the EU Directive is the permissible sludge load. As shown in Table 6.11, countries have chosen to legislate it either before or after the date the EU Directive came into effect.

Table 6.10: Limits for metals in soil in accordance with EU Directive 865/278/EEC (in mg/kg of soil)

Metal	Limit
Lead	50-300
Cadmium	1-3
Chromium	100-150 (tentative)
Cooper	50-140
Nickel	30-75
Mercury	1-1.5
Zinc	150-300

Source: EEC,1986

Table 6.11: Permissible load

Country	Average Annual Load, (t/ha)	Years of Single Annual Load (years)	Maximum Single Load (t/ha)
Austria	2,5	2	5
Belgium	1-4	3	3-12
Denmark	10	10	100
Finland	1	4	4
France	3	10	30
Germany	1.66	3	5
Ireland	2	1	1
Italy	2.5-5	3	7.5-15
Netherlands	1-10	1	1-10
Norway	2	10	20
Sweden	1	5	5
Switzerland	1.66	3	5

Source: ATV, 1996

The average amount of primary sludge produced in Western European countries is about 1.80 liters per-capita and day. This figure corresponds to an amount of 45 gr total solids per-capita and day and a moisture of 97.5%. Where combined systems exist, the mean weekly volume may be 25% higher. Secondary sludge from trickling filters is in the order of 0.63 liters per-capita and day and the excess sludge of activated sludge plants is 5,00 with the total solids and the moisture respectively 25 gr per-capita and day and 96.0% for trickling filter secondary sludge and 35 gr per-capita and day and 99.3 %for activated sludge plants.

In actual practice, however, the amount and general characteristics of the sludge varies greatly depending on the general composition of waste produced per-capita, the population equivalent of industrial sludge discharged into communal sewers, the system of stormwater collection and discharge, and the processes applied for the treatment of wastewater. The per-capita values and general composition of sludge from industry has been the subject of long-term records and the information has been published extensively. The impact of the system for the collection and discharge of stormwater has been referred to in Section 6.2.2. As regards the fourth determinant, the following should be noted:

- Primary sedimentation has been suppressed in some cases and countries for reasons of economy and as a measure to enhance the denitrification and aerobic stabilization of the sludge.
- Nitrification/de-nitrification is accompanied by a reduction in the volume and the organic content of the sludge.
- Phosphorus removal increases the amount of sludge.

- The choice of aerobic vs anaerobic sludge stabilization will greatly impact on both the amount and the composition of the sludge.

The disposal of raw sludge into the environment is no longer practiced in Europe. As of the end of 1998, the dumping of raw sludge or pumping onto land or into surface water is prohibited, and the disposal of sludge from municipal sewage treatment plants is regulated and is subject to registration and consent. An EU Directive concerning the deposition and incineration of sludge is in preparation.

There is considerable variation among the technologies chosen for the stabilization of sludge in Europe. The anaerobic digestion of sludge has been standards practice for a long period of time, especially for large plants in Germany, the Netherlands and Switzerland before legislation called for tertiary treatment. But aerobic stabilization aerobic stabilization is now an alternative especially for medium-size and smaller STPs. For large installations with more than one or several hundreds of thousands pe, the efficiency of anaerobic digestion has been greatly increased and the cost reduced by more effective processes, engineering design, and the equipment for the heating of digesters and the circulation of the sludge. The production of methane gas is an important factor in Western European countries where the cost of energy is high, and where the gas is commonly used as the primary source of energy. Similarly, where strict hygienic requirements exist, including for protecting workers of STPs, the anaerobic mesophilic process is considered advantageous.

Aerobic co-stabilization by the activated sludge process is chosen for an increasing number of STPs when nitrification/de-nitrification is applied. In these cases, the units for nitrification/de-nitrification are used additionally for the stabilization of sludge. For instance, in the but limited sample of STPs investigated in the course of the study referred to above, none of the facilities in France used anaerobic digestion. A new technology has been investigated for thermophilic aerobic stabilization but application of the process is slow, and research continues into the basic mechanisms involved, the most effective supply of oxygen, engineering design of the reactors, and operation and maintenance. The process may take place in the liquid or de-watered phase with essentially the same microbiological reactions involved. The process is also called “composting” though, generally, that term implies that the water content of the sludge would be lower than 92 to 95%. If de-watered further, the sludge is composted in bioreactors of various types with or without the addition of organic additives such as saw dust, bark, paper, or garbage. Composting is exhibited in Figure 6.7. On the left side of the Figure, composting in the liquid phase is depicted involving, as the first step, thermophilic aerobic stabilization followed by anaerobic finishing or mechanical de-watering or none. On the right side of the Figure, mechanically de-watered sludge undergoes composting in two stages with the addition of additives. In both cases, the final product is used in agriculture or landscaping.

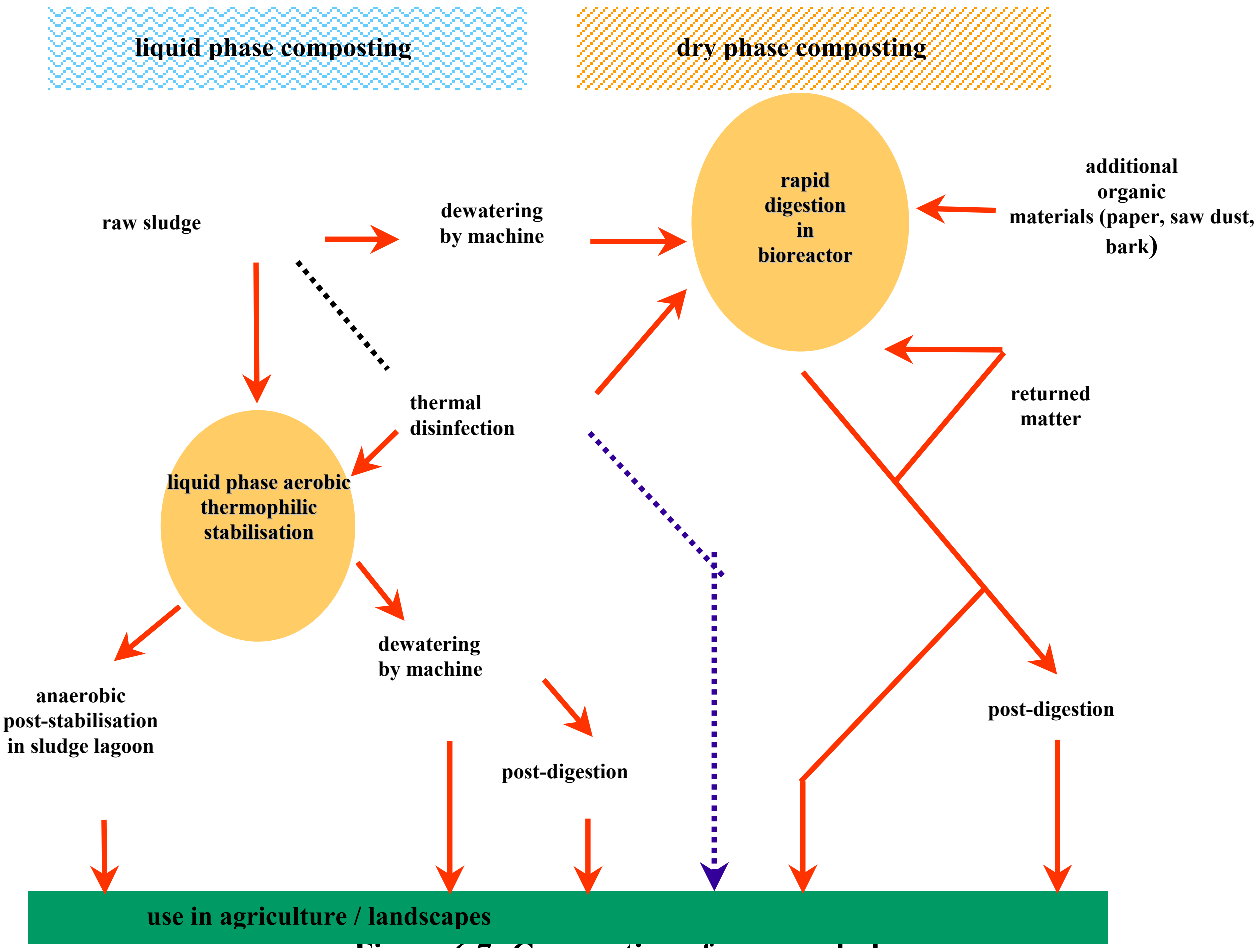

Figure 6.7: Composting of sewage sludge

Source: ATV, 1996

For de-watering, a variety of machinery is available but sludge drying beds are still being used in Europe. Filter presses and high performance centrifuges are now very common. They produce a sludge with 25 to 30% solids. If STPs serve less than 10 000 pe, stationary machinery may not be economical; in such cases, the sludge may be stored intermittendly and the de-watering accomplished by mobile equipment. For latest technologies, reference is made to the information presented at IFAT 99 (IFAT 1999).

6.4 Reuse (Topic d)

The direct reuse of treated effluent in agriculture is not a common practice in Western Europe though in the Mediterranean countries, some of the wastewater is reused to augment rainfall. In most of the Mediterranean countries, there is a water imbalance, especially during the summer months, e.g. Greece, Southern France and Italy and Spain. Intensive agriculture must be irrigated. Water demand for irrigation is rapidly increasing. Among the environmental priorities, water management in irrigated and drained areas and the proper use of non-conventional water resources stand out. Regarding the latter, the focus at this time is on the careful reuse of treated wastewater and use of other low-quality water. There is concern that projects for the reuse of wastewater will not impair acceptability of agricultural products and that no projects are implemented before the environmental and sanitary risk associated with the reuse are researched and tested in pilot operations.

EUREAU is in the process of establishing a database which will become available early in the year 2000; a preliminary report emphasizes the need for a EU guideline (or a Directive) to harmonize existing standards for the reuse of effluent (Angelikas et al. 1997), especially as regards the standard for faecal coliforms and intestinal nematodes. Standards are in effect in most of the countries but there are variations regarding faecal coliforms and other criteria, and the degree of prior treatment is still not satisfactory in many cases.

A case study on the reuse of treated effluent in Spain is contained in Section 6.11.3.

Two of the factors which deter the reuse of effluent in the Mediterranean EU countries have been, on the one hand, the yet considerable lack of adequate sewage treatment in some of the countries concerned and, on the other hand, the high cost associated with meeting the existing standards for the protection of public health. However, this will change in two ways during the next few years when the EU Directive 91/271/EEC will be implemented (see Section 6.6.1):

- A substantially increased amount of treated effluent will be available once the target set by the EU Directive for sewerage and treatment has been reached. Table 6.8 indicates that in some of the countries, secondary and tertiary treatment of considerable amounts of wastewater is yet to meet the Directive´s provisions.
- Article 12 of the Directive stipulates that “Treated waste water shall be reused whenever appropriate”. This implies that water pollution abatement considerations will supplement the agronomic demand for more reuse of treated effluent in the Southern part of Western Europe.

Concerning the reuse of sewage sludge, reference is made to Section 6.3.2. It has been discussed there that an increasing amount of sewage sludge is used in agriculture in EU countries. Information on permissible loads on land and limits for metals in soil have also been presented in that Section.

6.5 Disposal (Topic e)

6.5.1 Wastewater and stormwater

Most wastewater is discharged into surface water in EU countries though direct discharges into coastal water and estuaries and onto the land take place. Standards to be met by effluent will be described in Section 6.6.1, and basic information on the discharge of stormwater and reuse of water respectively in Section 6.2.2 and Section 6.4.

6.5.2 Sludge

Likewise, information on sludge disposal has been presented in Section 6.3.2 which deals with both the stabilization and utilization , and the disposal of sludge

6.6 Policy and institutional framework (Topic f)

6.6.1 Policy and standards

This Section gives primary attention to the development of wastewater and stormwater management in the context of policy and standards of the European Union.

The Treaty on European Union entered into force in 1983 and established environmental policy as one of the Union's task and linked sustainable growth to the need to respect the environment. The aims of this policy were to protect and improve the quality of the environment, to protect the health of the population, to make careful and rational use of natural resources, and to promote measures at the international level to overcome regional and broader-scale environmental problems. Instruments to pursue these aim were created, including:

- legal acts (primarily directives and quality standards for the environment), process standards (emission standards, design standards and operating standards), and product standards (maximum tolerable pollution levels or emission levels for a product).
- Action programs on environmental protection.
- Support programmes.

By now, all Western European countries have adopted national legislation for the collection, treatment and disposal of wastewater. However, of interest to administrators and scientist in other parts of the world at this particular time is the policy and legislation of the European Union rather than national legislation. Two types of EU legislation are of special interest:

- Regulations: They are the strongest form of Community legislation and have general application, are binding in their entirety and are directly applicable in all Member States.
- Directives: A Directive is a legal instrument by which the Council or the Commission can require the Member States to amend or adopt their national legislation by a specific deadline in order to achieve the aims set out in the Directive.

The European Council consists of the Heads of State or Governments is the Union´s supreme decision-making body. In contrast, the European Commission is its management arm and ensures the functioning and development of the Community. It is made up of the Commissioners and the administrative machinery that is under its control. Among the 26 Directorates-General, environmental matters are the responsibility of "DG IX" (the Directorate-General for Environment, Nuclear Safety and Civil Protection) which also controls the European Environment Agency (EEA) which is located in Copenhagen.

Water pollution control

Water pollution control is one of the major subjects of the forthcoming EU-Directive establishing a "Framework for Community action in the field of water policy" (EEC 2000). The Directive concerns surface fresh water, estuaries and costal waters, and groundwater. It lays down environmental quality though not limit values for pollution emissions with the exception of existing requirements, e.g. the "limit values" and "quality objectives" already established under the Dangerous Substances Directive of 1976 for mercury, cadmium, and hexachlorocyclohexane discharges. However, the Directive contains detailed Annexes dealing with immissions in surface waters, groundwater, and costal waters.

The overall purpose of the Directive is to establish a framework for the protection of inland surface water, transitional waters, coastal water and groundwater which, *inter alia*,

- prevents further deterioration and protects and enhances the status of aquatic ecosystems;
- promotes sustainable water use based on long-term protection of available water resources;
- aims at enhancing protection and improvement of the aquatic environment though specific measures for the progressive reduction of emissions, discharges and losses of hazardous substances based on the prioritisation of those of greatest concern.

- Moving towards the target of cessation of discharges, emissions and losses of hazardous substances by the year 2020, with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances.

The following concepts and procedures are noteworthy principal approaches stipulated in the Directive:
- Waster management via River Basin Districts.
- Assessment of the characteristics of each water-catchment area.
- Monitoring of the chemical, ecological and/or quantitative state of surface waters and groundwater in each water-catchment basin.
- Monitoring of protected areas within each water-catchment basin.
- Pollution-measurement programmes, including mandatory and optional measurements.
- Incorporation of all the above factors in a water-catchment basin management plan.
- Public consultation.

Of special interest is the provision that within each River Basin District, all bodies of water shall be identified which are used (and intended for future use) for the abstraction of water intended for human consumption providing more than 10 m^3 a day or serving more than fifty persons. Further, Member States shall ensure that under the water treatment regime applied, the resulting water will me the requirements of other concerned Directives of the EU; and still further, Member States shall ensure the necessary protection of water bodies so identified with the aim towards a reduction of the purification and pre-treatment needed in the production of drinking water.

The Directive identifies specific measures to be adapted by the Member States where the environmental quality standards are no longer met or where there is accidental pollution. It also puts forward a procedure for the notification and the exchange of information between Member States and the Commission and the EEA concerning management plans and draft management plans and other programmes referred to in the Directive.

It is important to note that the Directive requires Member States to ensure by 2010, a charging system for water services, which acts as an incentive for the sustainable use of water resource, and also that the various sectors of the economy, a distinction being drawn at least between domestic industrial and agricultural users, contribute fairly to the recovery of all the costs of water services having regard to the economic analysis conducted in accordance with the polluter pays principle.
River basin management plans are required for each river basin district. Special provision is made for international river basin districts falling entirely within the Community or extending beyond its boundaries.

The Directive also contains provisions for public information and consultation, reporting by the Commission on the implementation of the Directive, penalties, and a time table for action by Member States to bring into force the (national) laws, regulations and administrative provisions to comply with the Directive at the latest 3 years after it entered into force.

Urban wastewater collection and treatment

The basic legislation for the collection, treatment and disposal of wastewater in Western Europe is the Directive 91/271 of the EU Council of 21 May 1991 (EEC 1991), as amended by Commission Directive 98/15 of 27 February 1998. The Directive stipulates that Member States shall ensure that all agglomerations are provided with collection systems, and that the wastewater shall before discharge be subject to secondary treatment or an equivalent treatment as follows:

- Collection systems shall be provided at the latest by 31 December 2000 for agglomerations with a population equivalent (pe) of more then 15000, and, at the latest by 31 December 2005 for those with a pe of between 2000 and 15000.
- Secondary treatment or equivalent shall be provided by 31 December 2000 for all discharges from agglomeration of more the 15000 pe, and at the latest by 31 December 2005 from between 10000 and 15000 pe, and no later than 31 December 2005 for discharges to fresh-water and estuaries from between 2000 and 10000 pe.
- Moreover, the Directive stipulates further requirements for the removal of BOD_5, nitrogen and phosphorous depending on whether the discharge occurs into a “normal area” or a “sensitive area”. Responsibility for the identification of such areas rests with the Member States.

More specifically, the degree of treatment to be provided before discharge is exhibited in Table 6.12 unless Member States relax them in the light of local conditions.

Table 6.12: Collection systems, treatment requirements and time frames under Directive 91/271/EEC

Size of area Type of area	Less than 2000 pe	2000 to 10000 pe	10000 to 15000 pe	15000 to 150000 pe	More than 150000 pe
Sensitive	Collection syst. if any 2005 Appropriate treatment	Collection systems 2005 Secondary treatment	Collection systems 1998 Tertiary treatment	Collection systems 1998 Tertiary treatment	Collection systems 1998 Tertiary treatment
Normal	Collection syst, if any 2005 Appropriate treatment	Collection systems 2005 Secondary treatment	Collection systems 2005 Secondary treatment	Collection systems 2000 Secondary treatment	Collection systems 2000 Secondary treatment
Less sensitive (Costal water)	Collection syst. if any 2005 Appropriate treatment	Collection systems 2005 Appropriate treatment	Collection systems 2005 Primary or secondary treatment	Collection systems 2000 Primary or secondary treatment	Collection systems 2000 Secondary treatment

Source: EEC, 1991

A sensitive area must be identified if the body of water falls into one of the following groups:

- Natural fresh-water lakes, other fresh-water bodies, estuaries and costal waters which are found to be eutrophic or may become eutrophic.
- Surface fresh-waster intended for the abstraction of drinking water which contain more the concentration of nitrate laid down in the Council´s nitrate Directive 75/440.
- Any other area where further treatment is necessary to fulfill the purpose of the directive.

A less sensitive area is:

- A marine body of water if the discharge does not adversely affect the environment provided that there is no risk that the discharged load may be transferred to adjacent areas.
- Open bays, estuaries and other costal waters with a good water exchange and not subject to eutrophication or oxygen depletion or not likely to be so.

Figure 6.8 shows the sensitive and the less sensitive areas which have been identified by the Member States as of 1998, and Tables 6.13 and 6.14, respectively, indicate the removal rates for BOD5, nitrogen and phosphorous.

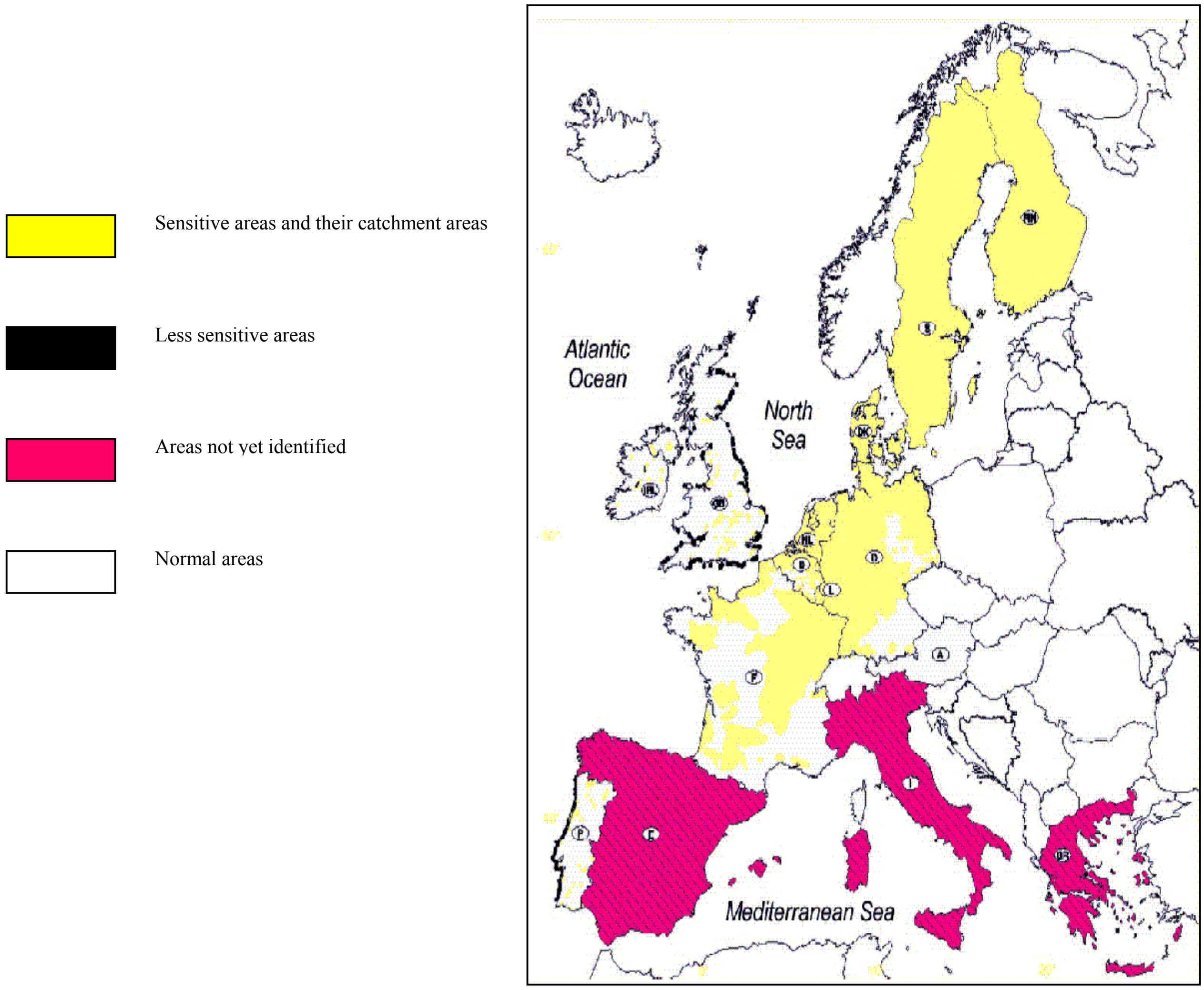

Figure 6.8: Sensitive and less sensitive areas

Source: EEA, 1999

Table 6.13: Requirements for discharges into normal areas (values for concentration or for percentage reduction)

Parameters	Concentration mg/l	Minimum percentage reduction	Reference method of measurement
BOD_5, without nitrification	25	70-90 40 in high mountain regions	Addition on a nitrification inhibitor
COD	125	75	Potassium dichromate
Total SS	35 60 in high mountain regions and 2000 to 10000 pe	90 90 in high mountain regions and 2000 to 10000 pe	Filtering through 0,45 um filter membrane Centrifuging at least 5 minutes at mean acceleration of 2800 to 3200

Source: EEC, 1991

Table 6.14: Additional requirements for discharges into sensitive areas (one or both parameters may be applied depending on the local situation)

Parameters	Concentration mg/l	Minimum percentage of reduction	Reference method of measurement
Total phosphorus	2 mg/l P (10000 to 100000 pe) 1 mg/l P (more than 100000 pe)	80	Molecular adsorption spectrophotometry
Total nitrogen*	15 mg/l N (10000 to 100000 pe) 10 mg/l N (more than 100000 pe)	70-80	Molecular adsorption spectrophotometry

*The sum of total Kjeldahl-nitrogen.
Source: EEC ,1991

The European Commission is responsible to monitor and report upon the implementation of Directive 91/271. A first report was due in June 1994 but has been published in 1998 only due to delays in national reporting (CEE 1998). The report includes information on implementation as of July 1998, viz. coverage attained and projections concerning with wastewater collection systems and treatment plants, meeting the obligation concerning industrial waste discharge respectively via urban collection systems and treatment plants and by direct discharge into receiving waters, quantity and methods of disposal of sewage sludge, and projected investment needed to meet the requirement both with respect to collection systems and treatment plants up to the year 2005.

Additional up-to-date information is contained in the report on Environment in the European Union at the turn of the Century (EEA 1999). The report states that after implementation of the Directive, the population not connected to sewers will be halved compared to the present situation; around 30 million persons or 5% of the total waste water will not be connected to sewers (see Table 6.15 and Figure 6.9). It has been assumed that no untreated wastewater will be discharged. The majority will either be treated by secondary treatment or secondary treatment plus nutrient removal. In Spain, Italy, Portugal and the United Kingdom the majority of wastewater will receive secondary treatment, while in Germany, France, Greece, Luxembourg, The Netherlands, and Finland the wastewater will also be treated in plants with nutrient removal. In the countries with no specific information on treatment after implementation of the UWWT Directive more than 80% in Sweden and Denmark today receive treatment with nutrient removal and only small changes due to the Directive can be foreseen. In Austria it is assumed that secondary treatment plus nutrient removal will be provided whereas in Belgium and Ireland there will be at least secondary treatment.

Table 6.15: Wastewater treatment in EU10* countries after implementation of Directive 91/271 (in million persons equivalent)

	DE	ES	FR	GR	IT	LU	NL	PT	FI	UK	EU10	% EU10
Rural population	5.7	0.4	13	2.5	3	0.003	0.2	1.3	1.1	2	29.2	5%
Untreated	0	0	0	0	0	0	0	0	0	0	0	0
Primary	0	10.2	3	0.1	4.2	0.03	0	2.1	0	11	30.6	6%
Secondary	2.5	70.3	6	1.3	87	0.1	0.2	10.9	0	55	233.3	44%
P+S+nutrient removal	121	4.2	54.5	8.6	10.6	0.48	24	1.2	5.5	13	243.1	45%
Total	123.5	84.7	63.5	10	101.8	0.61	24.2	14.2	5.5	79	536.2	100%

* EU10 countries include Germany (DE), Spain (ES), France (FR), Greece (GR), Italy (IT), Luxembourg (LU), Netherlands (NL), Portugal (OT), Finland (FI), and the UK (UK). Source: EEA, 1999

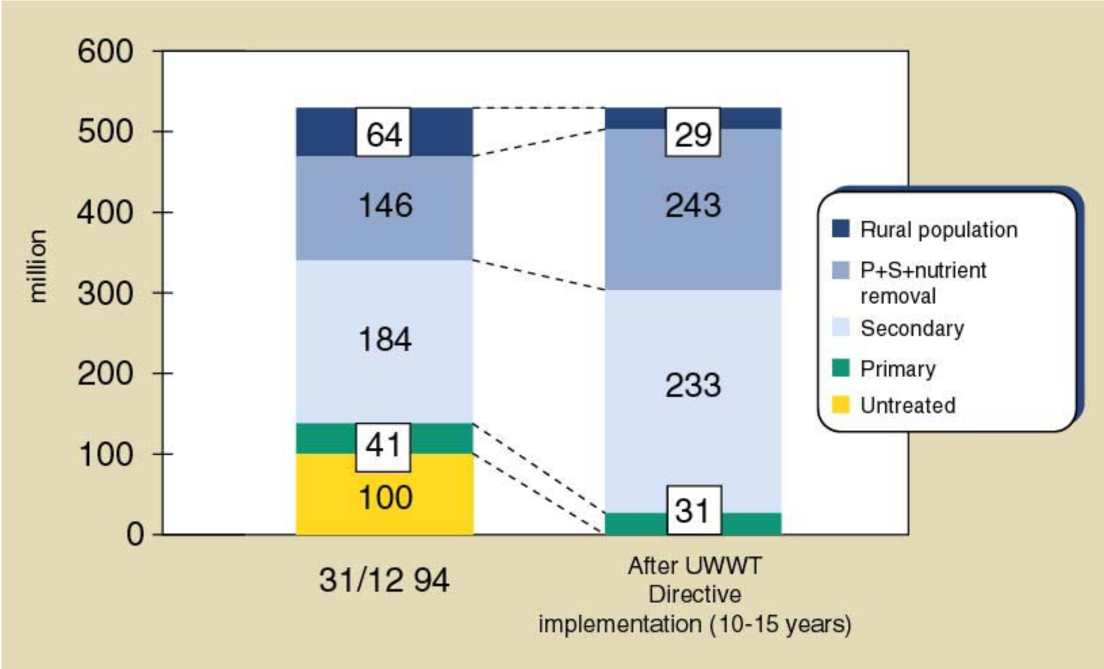

Figure 6.9: Development in the number of persons equivalents connected to different types of wastewater treatment in EU10

Source: EEA, 1999

As of now, all but one Member State have translated Directive 91/271 into national law and planned an implementation programme. In some cases was it necessary to take administrative action to ensure that implementation did follow the spirit of the Directive. The implementation programmes demonstrate that the timetable set forth in the Directive for combating 424 million pe pollution covering 90% of the population of the EU is realistic. Full implementation is expected before 2010 and should halve the population not connected to sewers from 64 to 29 million persons and upgrade the total wastewater discharged to sewers to 95%. Most wastewater will receive either secondary treatment or secondary treatment plus nutrient removal. The discharge of organic matter is expected to fall from 3..4 to 1.2 million tones BOD, a reduction of 65% from current levels,. In addition, phosphorous and nitrogen should decrease by 31% and 21% respectively (EEA 1999). The total investment planned is 130 billion ECU for wastewater treatment alone in 14 Member States of which 69 billion are planned for sewerage systems and 61 for STPs (CEE 1998). Per-capita cost is 140 Euro for wastewater treatment alone and 300 Euro for treatment plants and sewers together (EEA 1999). So far only two counties have indicated that the investment is not feasible in the case of one large metropolitan area, each.

Discharge of industrial wastewater into public collection systems

For the discharge of industrial waste into urban collection systems and urban wastewater treatment plants, the Directive 91/271/EEC obliges Member States to establish regulations and/or specific authorizations by the competent authorities or appropriate bodies. The industrial- waste should be subject to pre-treatment as is required in order to:

- Protect the health of staff working in collection systems and treatment plants.
- Ensure that collection systems, treatment plants and associated equipment are not damaged.
- Ensure that the operation of treatment plants and the treatment of sludge are not impeded.

- Ensure discharges from the treatment plants do not adversely affect the environment, or prevent receiving water from complying with other EU Directives.
- Ensure that sludge can be disposed of safely in an environmentally acceptable manner.

Industrial waste which does not enter urban wastewater treatment plants before discharge to receiving waters shall before discharge respect conditions established in prior regulations and/or specific authorization by the competent authority or appropriate body, in respect of all discharges from plants representing 4000 pe or more, especially waste from the following industrial sectors: milk-processing, manufacture of fruit and vegetable products, manufacture and bottling of soft drinks, potato-processing, meat industry, breweries, production of alcohol and alcoholic beverages, manufacture of animal feed from plant products, manufacture of gelatin and of glue from hides, skins and bones, malt-houses, and fish-processing industry.

Sludge arising from industrial wastewater treatment should be re-used whenever appropriate. Disposal routes must minimize the adverse effects on the environment. Member States must, further, establish general rules for the disposal of sludge from wastewater treatment plants. Dumping from ships or the discharge from pipelines or by other means is to be phased out. In the meantime, the Directive stipulates that the total amount of toxic, persistent or bio-accumulable materials in sludge disposed of to surface waters is licensed for disposal and will be progressively reduced.

Technical norms

In contrast to the legal standards described above, many technical norms must also be observed in Western Europe. They are issued by the respective standards institutions.

Standard institutions exist in most European countries. Internationally best known are the Association Francaise de Normalisation (AFNOR) of France, the British Standards Institution (BSI) of the United Kingdom, the German Institute for Standardization (DIN) of Germany, the Nederlands Normalisatie-Instituut (NNI) of The Netherlands, and the Swiss Standards Association (SNV) of Switzerland. A list of the national standards institutions in Europe is contained in Section 9.4. The oldest is the BSI which was established in 1901 followed by the NNI in 1916, the AFNOR and DIN in 1917, and the SNV in 1918. The official standards set forth by the national standards institutions in Western Europe are normally binding. Often, the are called “norms” and this terminology is used throughout the present Overview.

Less formal in character are the “technical standards” and, still less, the state of the art reviews established by professional associations in a number of European countries such as those of the Chartered Institution of Water and Environmental Management (CIWEM) in the UK or the Abwassertechnische Vereinigung (ATV) in Germany (see Section 6.8.1).

European integration after World War II had a profound influence on individual national standard setting when a Standards Committee was decided among the Members of the European Economic Community during the early 1960s. After discussion between the EEC and EFTA it was decided to set up the Commité Européen de Normalisation (CEN) covering both members of the Community and other West European countries. The Secretariat of CEN was first located in Paris but subsequently moved to Brussels, Belgium and incorporated under Belgian law. In 1986 it was agreed to supplement the Directives of EEC by “CEN European Norms”. The idea behind this decision was to keep highly technical matters out of the Directives but rather include them in the CEN norms. It was further decided that the European norms would be adopted by the countries without modification, and that the existing national norms would be substituted by the European norms as soon as they were agreed upon. New modes of agreeing on the norms were established calling for a vote; simple, however weighted majority vote is needed to put a standard into effect.

While the process of replacing the national standards by European norms is in no way completed it is nevertheless actively pursued (CEN 1998a). The new norms are of interest not only for the EU itself where they are one of the instruments to facilitated trade among its members, but also for other parts of the world. Hardware which meets the CEN norms is certified and awarded the logo “CE”.

For wastewater management, a number of European norms have already been finalized and published but many more will be available soon. This work was initiated in 1974 and first focused on appliances and apputerances used within buildings. Apputerances for use outside buildings were added and the first European standard was issued in 1985 and published in 1986. It covered street inlets and covers.

In response to an expanding programme of work, a Technical Committee TC165 for Wastewater Engineering was established in 1989. Its initial tasks were:

- Norms for the functioning, performance and installation of systems and components for wastewater engineering.
- Product norms for all types of components for sewer pipes.
- Norms for the design, dimensioning and use in wastewater technology, from the point of origin of the wastewater to the discharge into rivers.

TC 165 established Working Groups each of which is served by one of the national standards institutions as Secretariat. TC 165 is served by DIN. Other Technical Committees were established as indicated in Figure 6.10.

Figure 6.10 exhibits the full programme of CEN in the field of wastewater engineering from the point of origin to the point of discharge. It also contains information on the Committees responsible for norms for sanitary appliances, plastic piping systems, cast iron fittings, fittings and their joints, elastomeric seals for joints in pipework and pipelines, water analysis, and the characterization of sludges. Where no serial numbers are shown underneath subject items in the Figure 10, work is not yet completed, e.g.: grit chambers, primary treatment sludge treatment, sludge disposal, sludge utilization and stormwater and surface water analysis.

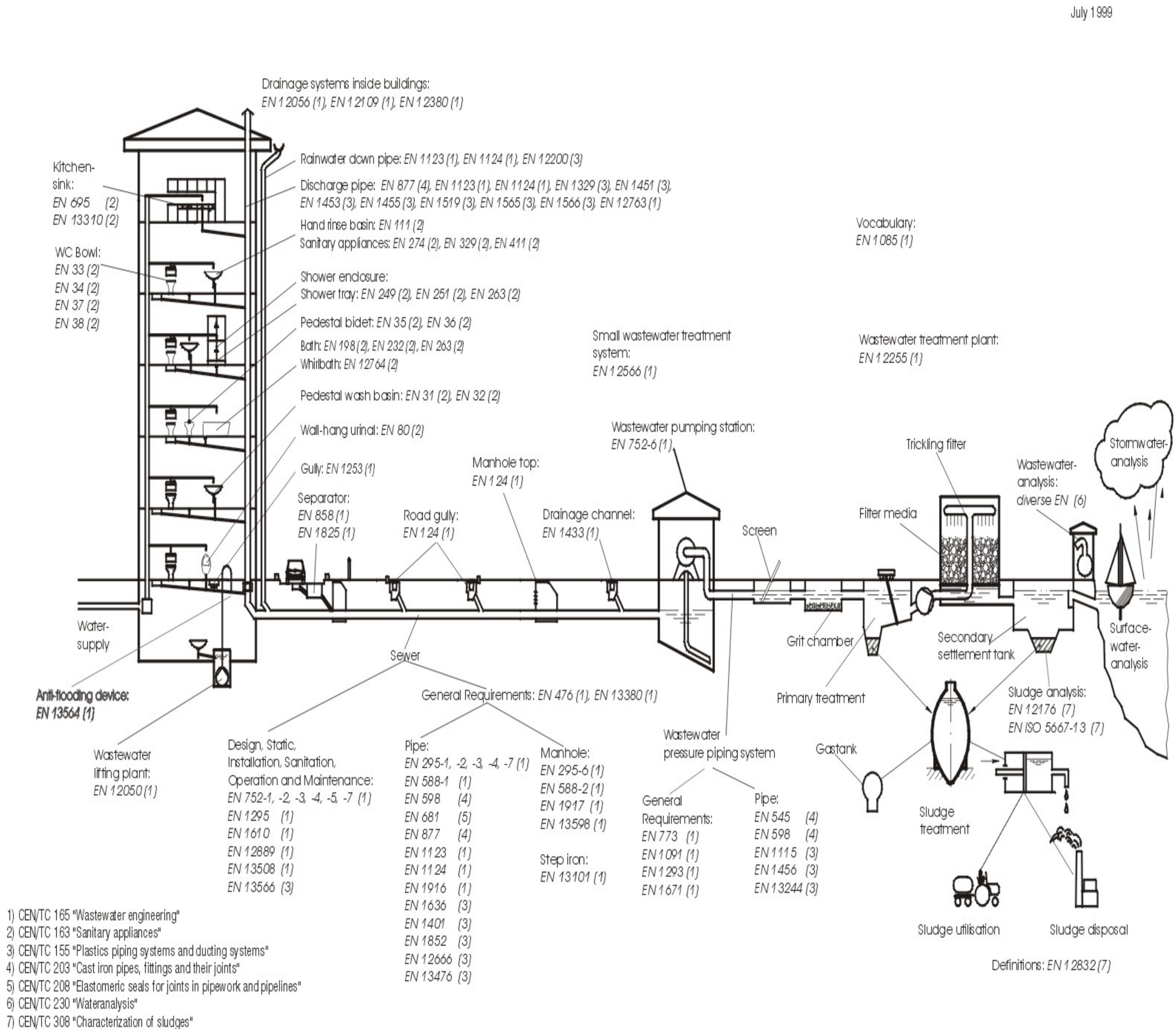

Figure 6.10: European Standards and Draft Standards in the field of wastewater engineering

Source: Courtesy DIN/TC165

As of 1998, 28 European norms for wastewater technology have been finalized and published, and 73 more were under preparation (see Tables 6.16 and 6.17). They will cover a wide gamut of subjects such as:

- Pipes and drains, e.g. fiber-cement pipes, vitrified clay pipes, longitudinal welded hot-dip galvanized steel pipes.
- Fittings.
- System components such as traps, anti-flooding valves, separators for light liquids or grease, effluent lifting plants for buildings and sites.
- Apputerances, e.g. components used in pneumatically pressurized discharge pipes, and air admittance valves.
- Small sewage treatment plants (less than 50 pe). Five norms will cover: prefabricated septic tanks; soil infiltration systems; packaged and/or site assembled domestic wastewater treatment plants; septic tanks built in situ from prefabricated kits; and filtration systems(including sand filters). The first norm on prefabricated septic tanks is at

the stage finalization under No. EN 12566-1; the others will follow (see also Section 6.3.1).

- Sewage treatment plants for more than 50 pe, comprising 16 parts, i.e. general construction principles; preliminary treatment; primary treatment; lagooning processes: activated sludge processes; biological fixed-film reactors; sludge treatment and storage; odor control and ventilation; safety principles; general data for dimensioning; control and automation; chemical treatment; disinfection; test procedures for the evaluation of aerator performance; and physical (mechanical) filtration.

The norms for pipes or drains and fittings are rather different from those for sewage treatment plants. The former focus on products and their performance. The latter cover the processes of sewage treatment, and their design and operation; they are not design manuals but rather stipulate the criteria which the designer must keep in mind.

Table 6.16: European norms which have been finalized and published (selected nos. only)

Registration No.	Title
EN 476:1997-07	General requirements for components used in discharge pipes, drains and sewers for gravity systems – Part 1: Generalities and definitions
EN 472-1: 1995-11	Same – Part 2: Performance and requirements
EN 752-3: 1996-07	Same – Part 3: Planning
EN 752-7: 1997-08	Same – Part 4: Hydraulic design and environmental considerations
EN 752-5: 1997-09	Same – Part 5: Rehabilitation
EN 752-6: 1998-04	Same – Part 6: Pumping installations
EN 752-7: 1998-04	Same – Part 7: Maintenance and operations
EN 1085: 1997-04	Wastewater treatment – Vocabulary
EN 1091: 1996-12	Structural design of buried pipelines under various conditions of loading – Part 1: General requirements
EN 1610: 1997-09	Construction and testing of drains

Source: CEN, 1998b

Table 6.17: European norms under preparation (selected nos. only)

Registration No.	Title
00165126	Anti-flooding valves for non-faecal and faecal sewage – Part 2: Testing principles, quality control
PrEN 274-1	Waste fittings for sanitary appliances – Part 1:Requirements
PrEN 274-2	Same – Test methods
PrEN 274 - 3	Same – Quality control
PrEN 588-1: 1996 rev	Fibre-cement pipes for sewers and drains – Part 1: Pipes, joints and fittings for gravity systems
PrEN 588-2	Same – Part 2: Manholes and inspection chambers
PrEN 733	General requirements for components used in hydraulically pressurized discharge pipes, drains and sewers
PrEN 858-1	Installations for separation of light liquids – Part 1: Principles of design, performance and testing, marking and quality control
PrEN 858-2	Same – Part 2: Selection of nominal size, installation, operation and maintenance
PrEN 1293	General requirements for components used in pneumatically pressurized discharge pipes, drains and sewers
PrEN 1255-1 to ..	Wastewater treatment plants for more than 50 pe – 16 parts (see text)
PrEN 12889	Trenchless construction and testing of drains and sewers

Source: CEN, 1998c

6.6.2 Institutional framework

The institutional frameworks existing in Western Europe vary as much as the countries themselves. The differences have their root in traditions; the legal framework; the ways in which big projects are financed in the country; and how and how effective money is raised, invested and recovered, and the finances controlled. They further derive from the perception of what is a public service and what is not; from the distribution of roles between the public and the private sectors and their respective strengths and weaknesses in the country, and, last but not least, from politics and political control.

In the following Sections, three different frameworks are described. The first may be considered the traditional approach. The other two frameworks command a great deal of interest in other parts of the world, viz.: the French experience in the management of water supplies and sewerage systems by private firms, and the privatization of the sector in England and Wales in 1989.

The traditional approach

Wastewater management grew out of other communal functions in almost all of the countries in Western Europe, among them the function of drainage. Still today on the continent, wastewater management is part and parcel of the management of municipal services in perhaps half of the municipalities. But the trend is away from this type of institutional framework because of the perennial lack of resources and the risk of political interference which have been plaguing wastewater management in many of the countries irrespective of their political color. While still within the municipal framework, about one third of the systems are now operated outside the municipal budget. In this case, they operate under a separate budget and must properly account income and expenditures but are still dependent in the legal and financial context. A gradual change-over to more financial independence has occurred in some very large European cities, e.g. Berlin and Hamburg in Germany where, in the overall, only little more 50% of the more than 10 000 STPs are still adhering to the traditional approach (see Figure 6.11).

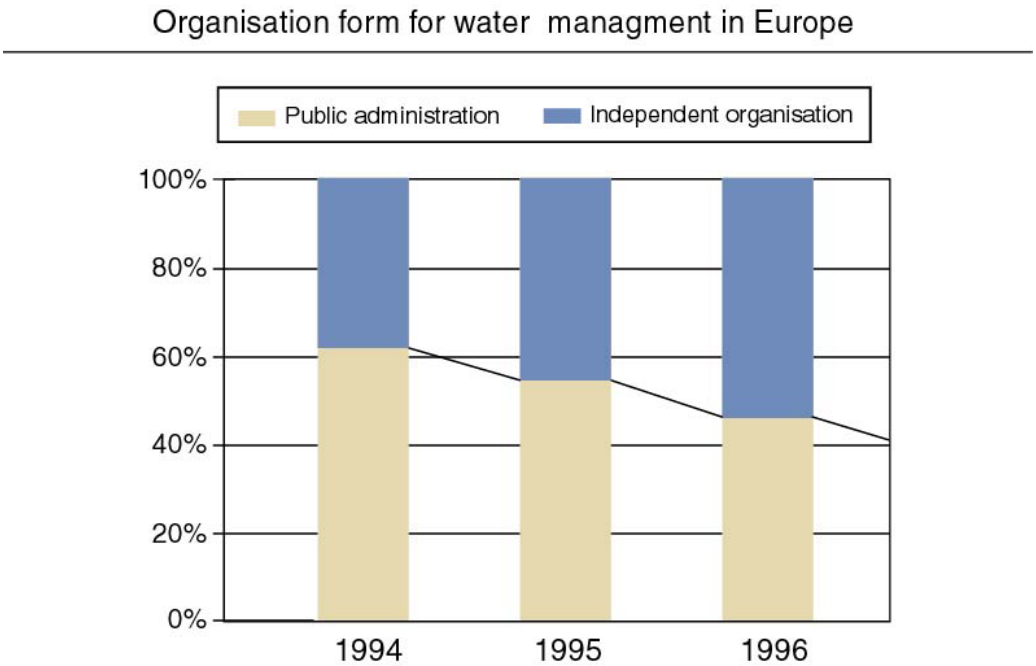

Figure 6.11: Development of organization forms in Germany

Source: ATV, 1999

From here onwards, entirely different models are being explored but not applied yet much in Europe. All involve increasing roles of the private sector. One model foresees operation and maintenance through private firms under a services contract; in this model, ownership of the facility rests with the municipality. Intermediate stages of privatization may involve the sharing of responsibility between the municipality and a private firm under a management contract with or without the municipality being the major shareholder; full contracting-out of all operations under a mixed equity contracts or a concession; or, finally, full privatization. These stages can be observed in France and in England and Wales and will be discussed below. Continental European countries may use these scenarios but in order to do so, they would first need to modify some of their existing policies and legal frameworks.

The French experience*

Like in its neighboring countries, wastewater management in France is basically responsibility of the municipalities (there are more than 30000). They have a choice to manage the facilities themselves or rely on private companies. This type of arrangement has been a part of France's history for more than a century beginning with water supply and gradually expanding to comprise the full gamut of urban public works. Five companies stand out viz. Companie Général des Eaux, Société Lyonnaise des Eaux. Société Générale et Lyonaise des Eaux, Société d´Aménagement Urbain et Rural, and Companie de Services et d´Environnement which together serve almost 80% of the population and more the 50% of the municipalities with water. The exception are the small municipalities because the law provides that management of water supplies within municipal budgets is not longer consented if their population is more than 3000. What has been said for water supplies applies fully also to the management of wastewater though still to a lesser degree.

Water supply and wastewater collection, treatment and disposal is considered a unit financially. Income and expenditure must be balanced. Rates are based on metering rather than other yardsticks. It follows that money for the management of wastewater can be raised by one and the same company if it is contracted for both services, as is increasingly the case.

The French system involves three partners but has fewer central controls than systems in England and Wales which are discussed below. They are the elected officials at the level of the municipalities, the user, and the private company. To fully appreciate this triangular relationship it is important to understand the status of elected officials at the local level of government in France, including the majors of the big cities. The more important the "monopoly" of the private company, the more will success or failure determine the outcome of local elections, and this variable represents the basic difference between France and in England and Wales where a central authority is supervising the service provider. Yet, the State also play a supervising role in France, partly through the Ministry of Environment and its Direction de l´Eau, and the Directions Régionale de l´Envirennement, partly through the River Basin Authorities created in 1994 which have power to set forth water policy and to coordinate between conflicting interests. The State also grants subsidies for construction, and these may be instrumental in ensuring compliance with both social and environmental policy and standards.

Once the municipality decides to delegate the operation of its system to a private company, a key instrument in the monitoring of the delegation is the contract signed between the municipality and the service provider. The contract is time-limited, and its provisions with respect to the services to be provided, responsibilities, liabilities and conditions of payment

* Excerpted from Lorrain, 1997

are governed by Law. The contract is the regulator to ensure that the service provider will live up to its obligation as regards service continuity and equal access in the spirit of social justice. Scholars of the system point out that the negotiation and re-negotiation of the contract is the decisive variable which makes the system work, and that self-regulation is possible.

There are other means of control. Firstly, service providers cannot act like a commercial enterprise because they are held not to exploit the monopoly. Secondly, competition among the service providers is strong, and reputation is a major factor in the their competitiveness Thirdly, the quality of the service rendered is a decisive factor in addition to the service fee.

Lorrain distinguishes four contractual settings each of which has implications for the responsibility and the commitment of the actors; he most suitable one from among them must be chosen (Lorrain 1997). With “limited delegation” only, the service provider operates on behalf of the authority on the basis of an operations or a management services contract. If a more substantial portion of the services is “partially delegated”, the duration of the contract is increased because the operator is expected make capital investment, assume risks while at the same time, enjoying a larger degree of freedom of action. In this case, the operator’s remuneration is derived from the authority rather than the consumer, and the authority retains ownership of the facilities.
“Total delegation”, either by a leasing agreement or a concession takes the case still further. Under French law, the service provider operates at its own risk, fixes prices, decides on the programme of the facility, and is in charge of hiring and hiring policy. The provider must take all the measures to provide the service and ensure continuity, including new investment. The authority remains the owner of all assets which are then handed over at the end of the contract in the case of non-renewal. Finally, in the case of “privatization”, the assets are sold to the provider who assumes responsibility for the complete works as is the case in England and Wales since the privatization of all water and wastewater services in 1989. Under this scenario, perpetual rights are vested in the operator while the local authority monitors performance.

In comparison with the British example, the practice in France is more flexible: for an individual case, any of the situations described above may be chosen in accordance with the local conditions. Further, locally elected officials, including the majors of big cities will dominate the decision making process rather than the State. Now that about 80% of the population are served by private companies in France, the system has begun to expand into other countries of Europe.

Privatization in England and Wales*

Under the Water Act 1989, all wastewater management in England and Wales was fully privatized. Ten regional water bodies were awarded separate “Appointments” as water undertaker and/or sewerage undertaker. The Appointment is an operating license for a minimum period of normally 25 year. The companies had to acquire the facilities. They are the sole owner and operator. However, if there is a breach by the undertaker of its general duty to supply water or provide sewerage, measured vis-a-vis UK and EU standards, the Appointment may be removed by order of the High Court at the request of the Secretary of State.

Within Europe, the privatization of wastewater management in England and Wales was a unique event because it was a nation-wide delegation of responsibilities to the private sector

* Excerpted from: Tyson, 1991

and was carried-out within a very short time. The ten companies were given full responsibility, accountability and power for long-term planning, implementation and operation. In the process of privatization, shares in the 10 companies were offered for sale to the general public and institutional investors in December 1989, and subsequently, were quoted on the London Stock Exchange where they have been traded freely ever since.

There were many reasons behind the decision to privatize. Among other things, was the political difficulty in raising, through general taxation, the substantial sums needed for investment in sewerage and sewage treatment. This has resulted in significant river pollution from inadequate combined sewer overflows, inadequately treated effluents and other problems such as structural and hydraulic deficiencies in the collection systems, especially in towns and cities which had grown rapidly since the 19th century. Recognition of the European standards for wastewater and drinking water treatment made it only too obvious that very significant capital investments, together with higher operating costs, would be required in the coming years. It has been observed that the public sector was too weak to address a problem of that magnitude for two reasons, at least, viz, treasury control of investment and borrowing and indirect control of prices all of which may look good on paper but cannot attract investment nor enhance consumer satisfaction; and political control resulting in short term policies for long term needs, sudden changes and sometimes political interference.

There had been a major reorganization in 1974 when the several thousand different local authorities or other public bodies responsible for water and sewerage were "nationalized" and reorganized in 10 water authorities. Although this gave the new authorities responsibility for the full range of water services and the aquatic environment, these authorities were still in the public sector and controlled by government with respect to investment and the price charged to finance the investment.

At that time, it was recognized that a number of inescapable requirements must be met whether water or sewerage business is in the public or private sector, viz.:

- The undertakers have a monopoly and, hence, have to be regulated.
- The service has to be provided safely, efficiently, economically and profitably.
- Effluent quality has to be improved to meet UK and EU standards, and the expectation of the general public.
- The higher expenditure to meet these standards will need to be financed by higher charges.
- Methods of charging need to be found so that the charge levied is as closely related to the benefit received.

Accordingly, the holders of an Appointment are tightly regulated at three levels by a Director-General of Water Services; a National Rivers Authority (which is the Environment Agency since April 1996); and a Drinking Water Inspectorate (not relevant for sewerage undertakers). These are the key regulators - there are other regulatory bodies with responsibilities for specific areas of business activity. In this system, Government (or the European Community) sets the standards; independent regulators check on compliance with the standards; and the private companies finance and implement projects to meet the standards.

The regulatory system is oriented on the interests of the customer. It ensures that customers are charged a fair price for service, that work needed to meet customer expectations can be financed, and that there is a reasonable return to shareholders. The reorganization of 1989 was a major undertaking carried out in a very short time. Thus, it is not surprising that the regulatory system appears stronger and more centralized than that in France where the role of the private sector has grown gradually over a period of more than 100 years.

The system works if each party fulfills its proper role, i.e.:

- The companies are required to give information to the Director-General for Water Services on the whole range of performance of their assets, e.g. the numbers and proportion unsatisfactory of combined sewer overflows, treatment works and sea outfalls, together with information on the flooding of sewers. They have to furnish underground asset management plans, including an estimate of the expenditure required to maintain and improve sewerage networks over at least a 15 year period. A report must also be made on actual expenditure and achievement in each financial year compared with the plan. Other conditions of the Appointment relate to charges, infrastructure charges and charges schemes.
- The Director-General has primary duty to ensure that functions are properly carried out throughout England and Wales, that the undertakers are able (in particular, by securing reasonable returns on their capital) to finance the proper carrying out of those functions. In exercising this primary duty, he must protect the interest of consumers and potential customers in respect of the charges and other terms of supply; promote economy and efficiency on the part of the undertakers; and facilitate effective competition between bodies holding Appointments as undertakers.

The main instrument of economic regulation is a price limitation formula set out in the conditions of the Appointments. This formula limits increases of principal charges made by the companies for the services they render. The percentage weighted average annual increase is limited to the sum of the percentage movement in the retail price index plus an adjustment factor, which may be positive, negative or zero. The factor was set in 1989 for an initial period of 10 years ending on 31 March 2000. The Director-General will carry out periodic reviews at 5 yearly intervals. The current investment programme totals more the 28 billion British Pound up to the year 2000. It may be expected that the already massive investment programme will increase.

6.7 Training (Topic g)

6.7.1 Education and training for planning and design

The education and training of specialists in wastewater and stormwater management, like that of other environmental specialist, has become more multi-disciplinary and multifaceted in recent years. This trend started with the inclusion of subjects from the related sciences into engineering curricula, especially chemistry and microbiology, but also biochemistry and physical chemistry, physiology and the associated analytical methods. Progressively, programmes are now also including subjects from the social and political sciences with the aim to prepare students and trainees for the complex tasks of environmental assessment, planning and management, e.g. economics and finance, law, planning theory, systems analysis, and social anthropology.

Almost all universities and many of the other educational institutions in Western Europe offer programmes in wastewater and stormwater planning and design as part of their civil engineering and/or water resources management curricula. Degree programmes may be part of the curricula for civil engineering, or may provide options for specialization in such fields as water supply, wastewater management, or water resources development. There are not many commonalities among the countries in this respect. Each country has its own tradition and framework. No up-to-date survey exists which would exhibit details on orientation, subject coverage or depth or length of the course. The best source of information are the national professional associations for water pollution control which exist in all Western European countries (for addresses see Section 6.10.1).

In addition to their regular academic programmes, several postgraduate programmes exist for environmental matters in some of the countries. Many of these are broad gauged and focus on meeting the needs for intersectoral and multi-disciplinary environmental planning and administration. However, there are also some specialized postgraduate programmes which focus exclusively on water-related matters, especially water supply and wastewater management. Most of these are open to students from developing countries. Four cases are summarized below (for addresses see Section 6.10.4).

Sanitary Engineering Master Programme of the International Institute for Infrastructural, Hydraulic and Environmental Engineering Delft, The Netherlands

The course ends with a MEng. (12 months duration) or a MSC (18 months) . Participants will be able to carry responsibility in preventing or managing sanitary engineering problems and/or, specifically, in the execution of project activities in sanitary engineering, and provide substantial technical inputs and participate in feasibility studies, and carry managerial responsibilities in the sector. The MEng. course emphasizes the application of scientific knowledge whereas the MSc. course includes research, laboratory and computer analysis, and modeling.

The full programme in sanitary engineering covers water supply, pollution control, and sector and utility management. The course starts with a common basic package including: introduction to sanitary engineering, process technology, chemistry, microbiology, unit operations, computer use, water resources assessment, water transport and distribution, urban drainage, water and wastewater treatment. Following this package, students can specialize water supply, pollution control, and sector utility management. Pollution control covers more advanced subjects such as waste prevention, treatment and disposal, solid waste management, cleaner production technologies, industrial wastewater treatment and sludge management. The final part of the course is devoted to writing an individual study report.

Imperial College of Science, Technology and Medicine, London, UK

The Department of Civil and Environmental Engineering offers a full time (12 months) course in Environmental Engineering with a MSC degree. Following the MSC, studies can be continued for a PhD degree.

The first half of the year is spent in lectures, tutorials and individual assignments. The second part consists of project work leading to a dissertation. Field work may be undertaken in the College laboratories, the Water Research Centre of the UK, or, partly at least, in some of the developing countries. The course is modular in nature and offers options in specialist subjects. Each module consists of about 30 hours of lectures per term. The following is an excerpt of the subjects available: water supply and distribution, water collection systems, water treatment, wastewater treatment, environmental engineering, chemistry, hydraulics, urban hydrology and wastewater collection systems, environmental microbiology, water and health in developing countries, and industrial wastewater treatment. Many of the specialized lectures are given by experts from water utilities, consultants, manufacturers and/or research institutions. Formal links exist with the London School of Hygiene & Tropical Medicine, and the Chartered Institution of Water & Environmental Management.

University of Newcastle, Newcastle upon Tyne, UK

The Department of Civil Engineering offers a 12 month course in Environmental Engineering and a MSC degree and a Diploma.

The course starts with compulsory modules (80 credits) in water chemistry and biology, water pollution assessment, waster supply engineering and infrastructure, wastewater engineering wastewater engineering design, solid waste management, and hazardous waste management. This is followed by a programme of optional modules (20 credits) chosen from a list which may include environmental modeling, environmental impact assessment, environmental engineering and water resources for developing countries, groundwater engineering design and construction, urban drainage, management and computing. A dissertation (80 credits) is based on a four-month research project.

Diploma students take the compulsory modules, fewer optional modules (10 credits) and a dissertation with 30 credits.

Bradford University, Bradford, West Yorkshire, UK

The Department of Environmental Sciences of the Faculty of Health and Environmental Sciences offers several MSc courses of interest, e.g. the course in Pollution Monitoring and Control. This course has evolved from the long-established degree programme in Environmental Monitoring and has strong ecological orientation and multi-disciplinary emphasis. It provides training in the various techniques normally available only is separate disciplines. The emphasis is on laboratory and analytical procedures. It covers chemical and biological monitoring, occupational and environmental pollution, environmental modeling, project development, and research methods. Options include: ecological principles and applications, environmental law, solid and liquid waste management, environmental acoustics and noise control, and environmental management techniques and processes. The part of the course dealing with wastewater emphasizes the current theory and practice of water and wastewater treatment both as a science and a technology.

There are related research and PhD programmes within the Departments of Environmental Sciences, and Environmental Engineering.

6.7.2 Education and training for operation and maintenance of wastewater works

The European universities do not offer full-time instruction on the operation and maintenance of wastewater works though some organize short courses and/or seminars dealing with related subjects but these do not normally cover the skills required at the artisan level for the day-to-day operation and maintenance of wastewater works. This type of instruction is normally provided by professional associations with or without the participation of the regulatory agencies involved. Four cases are described below. Most of the association also offer continuing education and training for specialists at the engineering and scientific level, and cover both planning and design and the operation and maintenance. For addresses, see Sections 6.10.1 and 6.10.4, respectively.

England and Wales

Two examples are noteworthy. Both involve private organizations which provide training at a charge.

The Certification and Assessment Board for Education and Training for the Water Industry

The Certification and Assessment Board and the Board for Education and Training for/in the Water Industry (CABRI/BETWI) carries out training aiming at improving O&M through training and better qualified staff, and ensuring that staff assigned will meet stipulated requirements. The key instrument in assuring a high quality of service are the National Vocational Qualifications (NVQs) which are established by the BETWI and applied (awarded) by the CABRI in consultation with industry experts and organizations. The two Boards function for the Water Industry in the UK. Thus, they are concerned with both water supply and sewerage systems

The National Vocational Qualifications (NVQs) are established and awarded to qualified personnel whereby a number of actors (persons and institutions) assume functions in the certification process, viz. verifiers, mentors/advisors, and the NVQ Centers. In most cases, it may take a person between 6 and 18 months to achieve a full NVQ depending upon the support his/her company gives in terms of time to collect evidence. Once obtained, an NVQ is for life. There are no exams. However, and “assessor” makes sure that the candidate meets the requirements as regards the knowledge and understanding. There is no general requirement for candidates to participate in training courses before undertaking an NVQ but workshops and courses are offered by some participating institutions.

Having an NVQ, the worker gains a recognized national, and increasingly, international qualification. His organization will gain the benefit of having a skilled workforce. The NVQ is also a tool to up-skill the workforce and/or the individual. Staff moral is boosted, and the NVQ can always be used as part of succession planning within the organization, and to reinforce organizational procedures.

There are five levels of attainment within the NVQ framework covering all levels of occupational performance and all areas of employment. For instance, level 1 requires competence in the performance of a range of activities most of which will be routine and predictable. In contrast, level 5 involves competence in the application of a significant range of fundamental principles and complex techniques of a wide and often unpredictable variety of contexts, and presumes substantial personal autonomy and often significant responsibility for the work of others and for the allocation of substantial resources features, accountability, design planning, execution and evaluation.

Further, there are some 20 NVQ “elements”. These may relate to water supply or sewerage systems. For each element, performance criteria, the range (of the tasks), the required knowledge and understanding, and evidence requirements are stipulated. An element may relate, for example, to “tracing water pipes and locating leaks” or “sewerage maintenance - rectifying faults and damage”. Other relate to sludge incineration or water quality surveillance. Monitoring of the sewage treatment process, and undertaking laboratory measurements are some of the many elements identified by the Board.

Water Training International

Water Training International (WTI) is a private training organization which provides UK based customized training programmes for students from the UK and a large number of other countries, including European as well as developing ones. Cooperative arrangements with many other organizations, especially with respect to the assessment (of qualifications) and accreditation.

WTI´s programme covers many subject besides water, e.g. building and facilities management, civil engineering, the environment, gas supply, health care premises and estate management, health, safety and risk assessment, management and supervisory, mechanical and electrical engineering, and public utilities distribution. However, a mainstay of WTI´s overall programme continues to be for "Water and Wastewater Design and Operation". More than 100 open courses were offered in 1996/97, such as: sewerage and sewage treatment design and maintenance (20), sewerage operation and maintenance (11), wastewater and trade effluent treatment operations (7), trench support, abrasive wheels and small plant (4), instrumentation (5), law, finance and administration (14), and technical overview (6).

France

Two examples are also described for France:

Programmes offered by private water companies

The continuing training of the personnel of the private companies discussed in Section 7 is given particular attention by each of these firms. They all maintain training facilities and provide instruction and practical field training. Extensive training material has been developed but has not been published. The example of one of these companies speaks for the system as a whole:

- A comprehensive training programme is carried out by the training center set up by the company covering technical and managerial aspects. The center integrates the training programme with the company's technical facilities, their central laboratory, and their technical offices for water treatment, hydraulics, O&M methodology, and research.
- During 1998, 108 activities were carried out for operating personnel (21 activities), for treatment works personnel (7) engineers and technicians (18), on informatics (17), administration (6), commercial aspects (5), management and human resources development (10), quality control (4), and safety (8).

Office International de l´Eau

The Office International de l´Eau, a government-sponsored yet independent organization, allocates about 50% of its resources to the continuing education and training at all levels and in many fields of water and wastewater, including operation and maintenance. It maintains a training center at Limoges. During 1998, forty-nine activities related to wastewater management: on sewers (12 activities), sewage treatment (17), pumping (3), central technical operations (6), maintenance (7), and on general management (4).

Germany

Several of the national water pollution control associations in Western Europe run programmes for operational personnel. The German model is of particular interest because in that country, operators of water supply and wastewater works are a legally recognized trade since 1984 as part of the national system which exists for the certification in many other trades. As part of this system, workers are trained at trade schools during their apprenticeship, and examined and certificated by government boards at the State level. Within the same system, "Master Technicians for STPs" were recognized already in 1987 for the operation of sewage treatment works. At the lower level, "Technicians" are trained for both network operations and STPs. The German Association for the Water Environment (ATV) has developed most of the training material and participates in the training and examination.

The system has enhanced the quality and the standing of operation and maintenance personnel and has helped to create beneficial conditions of employment, including negotiated remuneration. It has also been instrumental ameliorating the problem of the staffing of operation and maintenance which is plaguing sewage works in so many countries, especially the developing ones.

Training required to take the examination for certification recognizes three main fields, i.e. water supply, wastewater and solid waste. There are more than 10 000 sewage treatment plants in Germany and they employ about skilled 25000 workers. The ATV has trained more than 18000 during the last 35 years.

The scheme is exhibited in Figure 6.12 and information on the two categories of certificated technicians is included in Tables 6.18 and 6.19.

Table 6.18: Fields of activity and skills required of certificated Technicians

Certificated Sewer Technicians	Certificated STP Technicians
Field of activity: = Monitoring and servicing of network, operation and maintenance of pumping stations, vehicles, apparatus, aids, accident prevention and rescue equipment. = Execution of simple repairs. = Collaboration in monitoring indirect discharges on instruction by supervisors.	**Field of activity:** = Carrying out simple tasks on sewage treatment plants, including monitoring, operation and maintenance of machinery, equipment and aids. = Simple repairs.
Knowledge and skill required: = Purpose, types and properties of systems, including combined and separate systems, pressure and vacuum systems; and special structures. = On-site sanitation. = Sewer inspection with TV. = Methods for the cleaning of sewers. = Occupational risks and their prevention. = Keeping operational log.	**Knowledge and skill required:** = Water management, wastewater discharge, stormwater relief = Types, amounts and properties of wastewater and sludge. = Treatment processes and associated installations and machinery, and their functioning = Accident prevention: regulations, handling protective equipment. = Monitoring, operation and maintenance of facilities in accordance with instructions, operating data and measurements, and recognition of faults. Small repairs. = Simple measurements and evaluations. = Maintenance of an operational log.

Source: ATV, 1999

To take the exam for Master Technician, applicants must have three years experience as certificated operator before, or have 4 years experience in wastewater operations if qualified in a similar trade, or 5 years experience in the operation of a wastewater system if qualified in a dissimilar trade, or 8 years if without a trade qualification.

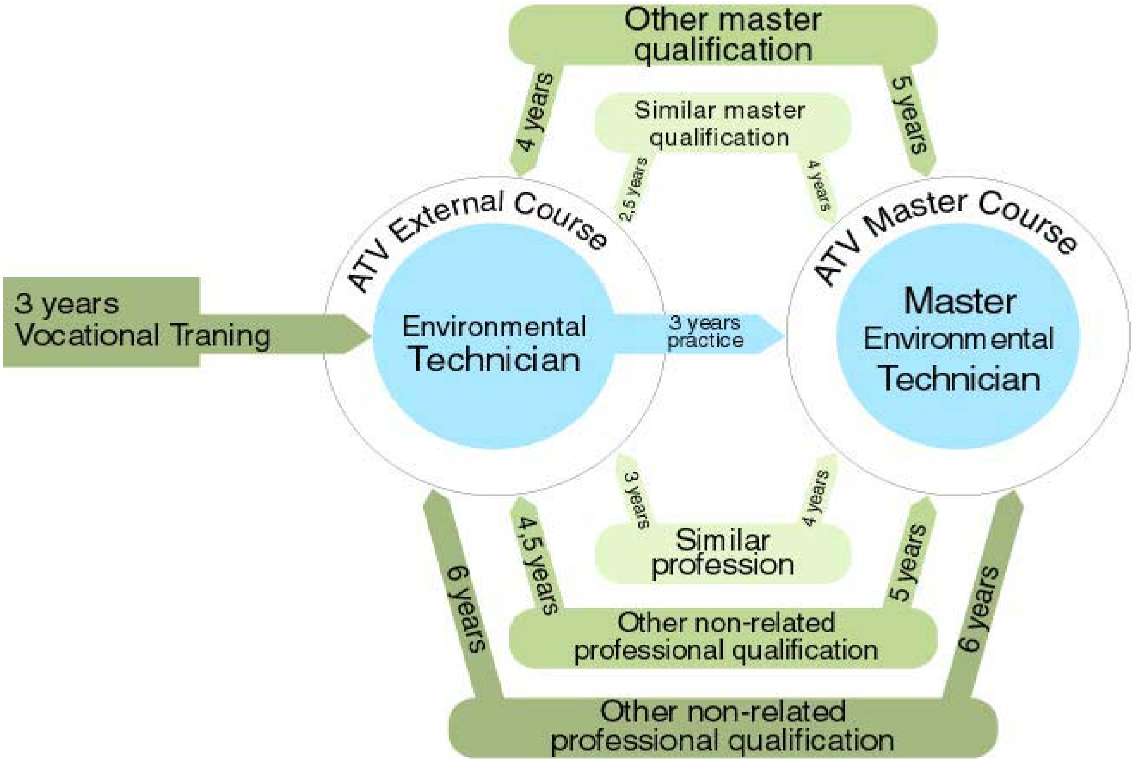

Figure 6.12: Prerequisites for Technicians and Master Technicians
Source: ATV, 1999

Taken together, the ATV runs a five-component programme as listed below. For all components, syllabuses and teaching material is available (the latter only for participants):

- ATV Basic Courses for skilled workers for sewer systems or sewage treatment plants.
- Preparation for the qualifying examinations for "certificated Sewer and/or Sewage Treatment Plant Technician". Table 18 exhibits their field of activity and the knowledge and skills they must have.
- Courses for "Master Technicians" the operation and maintenance of STPs. The courses are offered both formal or by correspondence. Once they have passed the Master´s examination, they are authorized to independently operate systems/plants serving a population of between 200 000 and 30 000. Table 19 contains a summary of the subjects covered during the training for master operator. They are authorized make independent decisions, including:
  - directing and managing the operation;
  - supervising the functioning of the process, the components and the machinery;
  - occupational safety and accident prevention;
  - training and supervision of operators;
  - participation in the planning of modifications of the system.
- Continuing education (at all levels of staff). Advanced training courses, seminars, info-days, specialists´ cooperation with universities, and group training with other specialist associations are organized and conducted.
- Continuing training in special subjects for supervisors and managers, engineers and scientists. For 1999, more than 80 activities are planned.

Table 6.19: Main subjects taught for Master Technicians for sewage treatment plants

Part 1: General
Basics of cost effective management
Basics of effective legal management
Basics of team work in operation and maintenance
Part 2: Technical
Mathematics, chemistry, physics and biology
Communication
Basics of data processing
Measurement and control mechanisms
Machinery
Scientific principles concerning wastewater collection and treatment – municipal and industrial
Occupational safety
Sewerage
Sewage treatment
Sludge treatment and use
Sampling and analytical methods
Processing of operational data
Legal provisions
Part 3: Vocational matters
Basics of vocational training
Planning education and training
Carrier development
Legal matters

Source: ATV, 1999

6.8 Public education (Topic h)

The general public of the countries of Western Europe is well aware of the need to protect the environment. Among the early stimulants which promoted awareness were the visible foams on many rivers in Western Europe associated with the widespread use of synthetic detergents soon after World War II, and the report for the Club of Rome under the title The Limits to Growth (1972). The report was available when the United Nations Conference on the Human Environment was convened at Stockholm in June of 1972. The impact of the Conference on public awareness has been great. Attention has focused strongly on the control of water pollution though other priorities included the pollution of the air in urban areas, the safety of food, noise, and the contamination of the environment by radio-nuclides. The latter was boosted after the nuclear accident at Chernobyl on 26 April1986.

Ecologist political parties formed in several of the countries. A "Green" group is now firmly established in the European Parliament, and "Green" parties are part of the governing coalitions in France and Germany. The environment has become an important variable in political decision-making. "Ecotaxes" are now levied in Germany on energy, and a EU-wide application of this approach is under discussion. Wastewater management does not normally figure as the No.1 priority in this process mainly because it has been generally accepted by the public as a matter of course.

Formal educational programmes focus on schools, and youth activities are promoted and supported by non-governmental organizations in all countries. As regards the adult population, environmental information is disseminated largely through the media but the impact of political debate is also increasing. But more often than not, the level of awareness is not yet matched by an appreciation and understanding of the level of the actual environmental stress and the level of impact on the ecology and/or human health resulting therefrom.

Public participation takes place mainly in two ways:

- At the local level, citizen groups and the media militate for environmental protection and advocate an appropriate level of funding for environmental action.
- At the individual level, participation takes place primarily through the family budget, e.g. paying sewer charges and the cost of wastewater treatment by the way of charges. There is general acceptance by the polluter/user-pays-principle, i.e. that the collection and treatment of wastewater have their price and that consumers must pay for it. This matter will be further discussed in the following Section 6.9.

6.9 Financing (Topic i)

6.9.1 Financing

The institutional frameworks existing in Western Europe (see Section 6.6.2) imply that financing of the wastewater and stormwater management is a responsibility of the municipalities and/or the private companies contracted for the operation and maintenance of the systems. Government may help but is not in charge.

Subsidies will to be gradually abolished in all sectors of the economy, including in wastewater and stormwater management. Yet, subsidies still exist and may amount to as much as 20% up to 30% of the initial costs in some countries. Cheap loans made by Governments to the municipality are more common. Several schemes exist in the light of enabling legislation for regional and/or rural development, agricultural development, or the environment. The municipality bear more than two third of the initial cost in most cases, and all the cost of operation and maintenance. Loans are repayable from the revenues arising from running of the facilities.

6.9.2 Cost

Cost calculation includes all cost which the owner or operator will have to meet annually with the view to ensuring a balanced budget and sound financial and fiscal management. These comprise:

- Capital cost, viz. interest, repayment and depreciation of the initial invest made.
- Cost of running the facilities and producing its output, viz. materials, consumables, spare parts, energy, laboratories, personnel expenditure and the general overhead.

The capital cost is calculated on the basis of the full investment without considering subsidies available from government or other sources The rational behind this approach is to create reserves for the replacement of the facilities once their life is consumed. Depreciation is normally taken at 15 to 20%. Interest is calculated on the basis of the total investment irrespective of the source of funding. Repayment follows the credit conditions; normally full repayment is made in 15 to 20 years.

In calculating the cost of operation and maintenance, the cost of the handling and ultimate disposal of sludge and other residuals is included. Under the condition of Western Europe, the personnel cost amount to about one third of the total cost of O+M. Rudolph reports (Rudolph 1997) that the total calculated cost break down roughly as follows (the percentages apply to Germany but the scheme stands in principle also for other parts of Western Europe):

- Depreciation: 20%.
- Interest: 40%.
- Personnel: 13%.

- Energy, sludge handling and disposal, and other miscellaneous O+M cost: 27%.

Of interest are two recent surveys comparing, respectively, networks and wastewater treatment plants. The first survey covered 12 countries, all of the EU and was basically conducted to assess stormwater pollution control (European Waste Water Group 1995). The second survey included Denmark, France, Germany, Italy, Switzerland and The Netherlands and was undertaken to analyze cost which must be borne by the undertaking (Fink *et al*. 1998). Wide variations exist from country to country and, therefore, the information presented is not intended for estimating the cost of a specific project.

The first survey contains information on the capital cost of providing new collection systems. The following are indicative ranges, as an average for a drainage area with a population of 10000: 300 to 375 ECU per meter in established urban areas, and 125 to 200 ECU per meter in open ground.

The second survey reviewed information on 6 treatment plants in each of but six countries. They were selected on the basis of recent construction, activated sludge or comparable biological treatment, nitrification and de-nitrification, phosphorus removal by chemical or biological methods, and size range. The analysis of cost data covered both construction and operation and maintenance. To enhance comparability, adjustments were made to compensate for differences in environmental standards, treatment effectiveness, sludge disposal, unit costs (of civil works, mechanical and electrical equipment, energy, labor and many others), design criteria, the percentage of connections, and the actual pollution load. Information varies greatly even after adjustments were made. For instance, construction cost for treatment plants in Germany and Switzerland are highest with about 450 Euro per capita. In The Netherlands, they are about 65% of that value and in France, Italy and Denmark, between 30 and 40%. The variations of the cost of operation and maintenance are similar. Table 6.20 is a summary of the information reported.

Table 6.20: Cost of construction and operation and maintenance of sewage treatment works

Country	Weighted average of adjusted cost of construction (Euro/capita)	Weighted average of adjusted cost of O+M (Euro/capita,year)
Denmark	215	23
France	150	17
Germany	460	20
Italy	154	20
Switzerland	440	22
The Netherlands	303	22

Source: Fink, *et. al.* 1998

6.9.3 Recovery of cost

Cost recovery from the user of the facilities is considered the only valid approach to creating revenues for wastewater and stormwater management in Western Europe. Several methods are available, e.g.:

- Community fund raising, e.g. ad-hoc contributions, revolving funds, communal levies.

- Indirect taxes.
- Wastewater charges.

The levy of wastewater charges is the principle method used and will be summarized below. The information presented is based on two highly commendable surveys (Schoot Uitercamp 1995 and Rudolph 1998). The emphasis is on methodology rather than numerical values since to large measure, the latter depend on the service levels, i.e. the coverage by collection systems and sewage treatment plants and the degree of wastewater treatment achieved. The survey undertaken in 1995 comprised the then 12 Member States of the European Union; the survey of 1998 was limited to 6 countries of the Union (Austria, Denmark, France, Germany, Italy and England and Wales).

It is very important to understand that in Europe, wastewater charges serve two functions:

- To finance collection systems and treatment facilities (finance function).
- To stimulate polluters to reduce their emissions (incentive function).

As regards the incentive function, it is not considered important how the revenue is spent because the incentive effect works through the design of the charge itself not via its spending. In contrast, the finance function is inextricably linked with the way the revenues are applied. The polluter-pays-principle (ppp) is widely accepted and also reflected in the EU Directive on water policy (see Section 6.6.1).

Table 6.21 shows how France, Germany, The Netherlands, Spain, and England and Wales are adding the pollution load to the more routine fixing of the charge in accordance with the finance function.

The 1995 survey shows that the systems for fixing wastewater charge in the countries of the European Union vary widely with respect to:

- Type of discharge, i.e. direct discharges, indirect discharges or both.
- Target groups, i.e. household, small firms, large firms and communities.
- Revenue spending, e.g. for sewage treatment, sewerage, water quality management, or subsidies to industry.
- Charge base, e.g. pollution load, sector coefficients, water consumption or fixed rates.
- Pollution load, e.g. types of pollutants, weights in a charge formula, or choice of pollution unit.
- Charging agency, e.g. River Basin Authority or Water Board, regional or local unit of administration, private water company.
- Context: in the context with issuing permits, or exercising responsibilities for water pollution management.

In most countries, the charges for direct discharges are different from those for indirect discharges with the exception of Belgium, France and the Netherlands which cover both in one scheme. Target groups for indirect discharges all include industrial discharges and discharges of households and small firms but for direct charges, they include industries, communities and/or households and small firms. Revenues from indirect discharges are all applied to finance communal sewerage and treatment plants only. In the case of direct discharges, revenues are applied in a wider context, e.g. financing water quality management in general, consenting, subsidies, etc.

The fixing of wastewater charging schemes covering, on the one hand, discharges to surface water in the Member States of the European Union, and, on the other hand, discharges into sewerage systems is exhibited in Tables 6.21 and 6.22. In the two Tables, the charging schemes are classified with respect to :

- Design of the schemes, viz. the by central authorities (NAT) or locally (LOC):
- Charging authority, viz. the central or regional units of administration (ADM), Water Basin Agencies or Water Boards (Municipalities (MUN), or private companies (PRIV).
- Discharges covered, viz. for household and small firms (HOU), industries (IND) or communities (COM).
- Spending of the revenues, viz. for communal treatment works (TRE) involving partial or complete financing of construction and/or operational cost, subsidies for treatment at industries (TEIND), sewerage (SEW) or water quality management (WQM).

Table 6.21: Wastewater charging schemes covering discharges to surface waters in EU countries

Country	Design	Authority	Dischargers	Spending for
France	NAT	WBA	HOU, IND,COM	TRE, TEIND
Germany	NAT	WBA, ADM	HOU, IND, COM	TRE, WQM
Netherlands	NAT	WBA, ADM	HOU, IND, COM	TRE, TREind, WQM
England and Wales	NAT	WBA	IND, COM	WQM
Spain	NAT	WBA	IND, COM	TRE, TEIND, WQM

For acronyms see text.
Adapted from: J.F.J. Schoot Uitercamp, 1995

The two Tables are too compact to include specific information on the methods used for the actual calculation of the charges. However, this information is contained in Volume 2 of the survey report which comprises “Country Descriptions” each of which includes a Section on the calculation of the charge.

As pointed in the following table, wastewater charges are seen increasingly as instruments to control pollution at the source and just for financing cost. For a charge scheme to fulfil the incentive function, there has to be a link between the payable charge and the actual pollution load of the discharge. Also, the incentive will be limited to those pollutants which are considered in the scheme. In the overall, the charge rate is the crucial variable for an incentive effect in practice because it determines whether it is economically beneficial for a discharger to abate pollution (e.g. by pre-treatment) or to pay the charge. Therefore, the higher the charge, the higher will be the effect. The link between the load which is ultimately discharged by a polluter, on the one hand, and the payable charge, on the other hand, is the essential condition for the successful application of concept. To satisfy this condition, the charge may be based on:

- The discharger´s pollution load via measurement of the emission, or via the value stated in the discharges permit.
- Sector-specific coefficients with the option of measurement.
- Indirect variables, e.g. sector-specific coefficients without measurement, a proxy (such as the water consumption) or a fixed amount.

Table 6.22: Wastewater charging schemes covering discharges to sewers in EU countries

Country	Design	Authority	Discharges	Spending for
Denmark	LOC	MUN	HOU, IND	TRE, SEW
France	NAT LOC	WBA MUN MUN	HOU HOU, INDsm HOU, INDsm	TRE, TEIND TRE, SEW TRE, SEW
Germany	LOC	MUN	JOU, IND	TRE, SEW
Greece	LOC	MUN	HOU, IND	TRE, SEW
Ireland	LOC	MUN	HOU, IND	TRE, SEW
Italy	NAT	MUN	HOU, IND	TRE, SEW
Luxembourg	LOC	MUN	HOU, IND	TRE, SEW
Netherlands	NAT	WBA	HOU, IND	TRE, WQM
Portugal	LOC	MUN	HOU, IND	TRE, SEW
Spain	LOC	MUN	HOU, IND	TRE, SEW
England and Wales	NAT	PRIV	HOU, IND	TRE, SEW

For acronyms see text.
Adapted from:J.P.J. Schoot Uiterkamp,1995

Table 6.23 exhibits the pollution parameters considered in fixing incentive charges for communal discharges and the other variables used in determining the pollution load. They are:

- Pollution parameters, viz. suspended solids (SUS), organic matter (ORG), heavy metals (MET), nutrient phosphorus (P), nutrient nitrogen (N), halogenated hydrocarbons (AOX), a toxicity indicator (TOX), soluble salts (SOL), or as a system in which the discharge is classified in "Bands" to which values are attached (BND).
- Other determinants, viz. the number of inhabitants in a community (INHAB), a sector-specific coefficient (COEF), actual measurement of the load (MEAS) or optional measurement (MEASO), or a value based on a discharge permit or consent (PERM).

Table 6.23: Determination of the charge for communal discharges (incentive function)

Country	Pollution parameters	Other determinants
France	SUS, ORG, MET, P, TOX, AOX, SOL	INHAB, COEF, MEASO,
Germany	ORG, MET, N, AOX	TOX, PERM, MEASO
Netherlands	ORG, MET, N	MEAS
Spain	BANDS	PERM
England and Wales	BANDS	PERM

For acronyms see text.
Adapted from: J.F.J. Schoot Uiterkamp, 1995

Volume 2 of the survey report of 1995 contains several Tables exhibiting the determination of incentive charges for large industrial discharges but the limited space available for this Overview does not allow inclusion.

In the 1998 survey (Rudolph 1998), several additional factors were analyzed which influence cost and cost recovery in the 6 EU Member States included in the survey though differently from country to country. They are:

- Subsidies. They may be as high as 30% of the construction cost and may or not be made subject to the calculation of charge rate as regards their finance function.
- Added Value Taxes (TVA).They may be payable whenever private enterprises are involved in the construction and/or operation and maintenance of the facilities.
- Communal or other levies. They may comprise connection charges or infrastructure charges.
- Water consumption.
- Stormwater. Stormwater is a communal function and chargeable to the general tax revenues in many of the European countries.
- Disposal of residues, e.g. sludge and screenings.

Tables 6.24 and 6.25 exhibit cost and charges as derived from the survey adjusted in the light of the above-mentioned factors to enable comparison between the countries.

Table 6.24: Annual per-capita cost (Euro)

	Austria	Denmark	France	Germany	Italy	England and Wales
Calculated values	77	137	126	228	120	77
Adjusted values	154	133	118	168	106	105

Adapted from: K.-U. Rudolph, 1998

Table 6.25: Annual per-capita charges (Euro)

	Austria	Denmark	France	Germany	Italy	England and Wales
Calculated values	78	93	68	110	20	66
Adjusted values	69	79	92	100	116	77

Adapted from: K.-U. Rudolph,1998

6.10 Information sources (Topic j)

Information sources are listed below according to categories.

6.10.1 European Water Association (EWA), previously the European Water Pollution Control Association (EWPCA)

Address: Theodor-Heuss-Allee 17, D-53773 Hennef, Germany
Telephone: +49 22 42 87 20
Fax: +49 22 42 87 21 35
Email: vanries@atv.de
Contact: Dr. Sigurd van Riesen

Topics covered: Wastewater and stormwater collection, transfer, treatment and disposal. Water pollution control. Solid wastes.

Description: The EWA is an association of professional European organizations. Its members are first and foremost, 29 professional associations in these fields of which 19 are in Western Europe. The objectives of EWA is to promote the advancement of water pollution control technology, provide a forum for discussion among members and with the European Commission, to assist in new Directives of the EU, and support the European Committee for Standardization (CEN). The association organizes and sponsors workshops, seminars and conferences and publishes the bimonthly magazine European Water Management. It has a European Technical and Scientific Committee (ETSC) consisting of 12 members from as many countries under the chairmanship of Mr. Conradin of Switzerland, which has set up Working Groups on sewerage systems, wastewater treatment, receiving waters, effluent standards, sludge treatment and professional education and training. The Secretariat of EWA is co-located with the German Association for the Water Environment (ATV) and its Secretary-General is Dr. van Riesen.

The national member association have a membership of some 50 000 specialists in various fields of wastewater management and are, thus, information sources of almost unlimited scope in many different languages. The easiest access to the national member associations is via the EWA.

Format of information: Journal, reports, books and proceedings; conferences, seminars, workshops and other training activities. Some of the national member associations publish their own journals. Inquiries may be directed either to EWA.

Languages: The languages of the national member association. In addition mostly English or French.

Consulting or support services: EWA will provide services though its central office or refer requests to its national members.

Fees: Publications and participation in conferences and training activities are charged.

6.10.2 On-line information sources

EAUDOCplus

Address:	15, rue Edouard Chamberland, 87065 Limoges Cedex, France
Telephone:	+33 555 11 47 80
Fax:	+33 555 77 72 24
Email:	snide@oieau.fr

Internet:
http://www.oieau.fr/anglais/eaudoc/documen.htm

Topics covered: All subjects related to water and wastewater: technical, management, administrative, legislative.

Description: This service is part of the International Office for Water, a non-profit association under French law since 1991. EAUDOCplus provides information, documentation, references, abstracts, studies and syntheses, and hard copies of publications of interest. The International Office for Water is located at:

Address:	21 rue de Madrid 75008 Paris, France
Telephone:	+33 144 90 88 60
Fax:	+33 140 08 01 45
Email:	dg@oieau.fr

Format of information: data, studies, inventories of research, syntheses of information, abstracts, hard copies. Seminars, workshops and training sessions.

Languages: French and English.

Consulting: Through the International Office for Water.

Fees: Services are charged.

AQUALINE

Address:	Frankland Road, Blagrove, Swindon, SN5 8YF, UK
Telephone:	+44 1793 865 000
Fax:	+44 1793 865 001
Email:	Aqualine@wrcplc.co.uk
Internet:	http://www.aqualine.co.uk/

Topics covered: The entire hydrological cycle including sewerage, outfalls, irrigation, water re-use, sewage treatment processes, sludge treatment and disposal and industrial effluent treatment.

Description: This service is part of the Water Research Centre (WRc) of the UK (same address). Its services include references, abstracts, syntheses, and documentation. Aqualine is a resource for scientists, engineers industrialists and information specialists.

Format of information: abstracts, databases, copies of articles, studies and searches, syntheses. Workshops and other training activities.

Languages: Basically English but also other languages, as may be required.

Consulting and support: Through the Water Research Centre.

Fees: Services are charged.

6.10.3 International research and reference organizations.

Those listed are Europe-based and have programmes of particular interest to developing countries.

Topics covered: Water supply, sanitation, wastewater management, waste disposal.

Description: The international research and reference organizations listed below undertake research and/or serve as switchboards and clearing houses for water supply, sanitation, wastewater management and waste disposal, and maintain extensive specialized data bases, undertake studies and research and train at both the professional and artisan levels.

Format: Data bases, reports, and publications. Seminars, workshops and other training activities.

Languages: English, French and their national language.

Consulting and support: Consulting on and supporting the development of research and reference services.

Fees: Services are normally charged.

EAWAG – SANDEC, Department of Water & Sanitation at the Swiss Federal Institute for Environmental Science and Technology

Address: Ueberlandstrasse 133, CH.8600 Duebendorf, Switzerland
Telephone: +41 1 823 55 18/55 11
Fax: +44 1 823 53 99
Email: schertenleib@eawag.ch

IRC International Water and Sanitation Centre

Address: P.O. Box 2869, 2601 CW Delft, The Netherlands
Telephone: +31 15 219 09 39
Fax: +31 15 219 09 55
Email: general@irc.nl

WEDC Water, Engineering and Development Centre

Address: Loughborough University, Leicestershire LE11 3TU, UK
Telephone: +44 1509 222 885
Fax: +44 1509 211 079
Email: WEDC@lboro.ac.uk

6.10.4 Institutions offering post-graduate programmes of interest to developing countries, and training for operation and maintenance (as reviewed in Sections 6.7.1 and 6.7.2)

Post-graduate programmes

Topics covered: Water supply, wastewater management, waste disposal, sanitary and/or public health engineering.

Description: The four sources of information listed below are university institutions and run postgraduate courses related to water supply, wastewater management, and waste disposal as described in detail in Section 6.7.1.

Format: Degree programmes, research and studies.

Languages: Basically English.

Consulting and support: They consult and support other teaching institutions in the planning and development of their own programs.

Fees: Post-graduate training is charged.

International Institute for Infrastructural, Hydraulic and Environmental Engineering

Address: 2601 DA Delft, The Netherlands,
Telephone: +31 15 215 17 15
Fax: +31 15 212 29 21
Email ihe@ihe.nl

Imperial College of Science, Technology and Medicine

Address: Exhibition Road, London SW7 2AZ, UK
Telephone: +44 171 589 51 11
Fax: +44 171 225 27 16
Email: c.j.kerr@ic.ac.uk

Newcastle University

Address: Newcastle upon Tyne NE1 7RU, UK
Telephone: +44 191 222 60 00
Fax: +44 191 222 61 39
Email: webmaster@ncl.ac.uk

University of Bradford

Address: Bradford, West Yorkshire BD7 1DP, UK
Telephone: +44 1274 232 323
Fax: Same
Email: pg-admissions@bradford.ac.uk

Operation and maintenance training

Topics covered: Operation and maintenance of sewer systems and sewage treatment plants. In some cases, the organizations listed also cover water supply and other technical subjects.

Description: The four organizations cover the skills required at the artisan level for the day-to-day operation and maintenance of wastewater works as described in detail in Section 6.7.2. They are professional/training organizations which operate normally in consultation and/or participation of the regulatory agencies involved. They also offer continuing education and training for specialists at the engineering and scientific level, and cover both planning and design and the operation and maintenance.

Format: Formal and/or correspondence courses, qualifying examinations, certification.

Languages: English/French and their national languages.

Consulting and support: Con consulting and supporting the planning and development of similar activities in other countries.

Fees: Services are charged.

The Certification and Assessment Board for the Water Industry

Address: 1, Queen Anne´s Gate, London SW1H 9BT, UK
Telephone: +44 171 957 45 23
Fax: +44 171 957 46 41
Email: ian@cabwi.demon.co.uk

Water Training International

Address: Tadley Court, Tadley, Basingstroke Hampshire RG26 3TB, UK
Telephone: +44 118 981 30 11
Fax: +44 118 981 70 00

Office International de l´EAU

(See Section 6.10.2)

ATV-Vereinigung für Abwasser, Abfall und Gewässerschutz

Address: Theodor-Heuss-Allee 17
Telephone: +49 22 42 87 20
Fax: +49 22 42 87 21 35
Email: vanries@atv.de

6.10.5 Standard organizations

For Europe-wide information and information on European Norms

European Committee of Normalization (CEN)

Address: B-1050 Brussels, Belgium
Telephone: +32 2 550 08 11
Fax: +32 2 550 08 19
Email: cen @cenclcbel.be
Internet: www.cenorm.be

Topics covered: The work of CEN covers 15 Sectors of which the "Water Cycle" is one.

Description: CEN´s programme related to wastewater management is delegated to DIN (German Standard Institute) serving as the Secretariat of the Technical Committee CEN/TC 165 "Wastewater Engineering" as described in detail in Section 6.6.4 (for address, see below).

Format: European Standards (EN), European Prestandards (ENV), Reports for information and transfer of knowledge (RC), Workshop Agreements aiming at consensual agreements from open Workshops with unrestricted direct access of interested parties (CWA), and Certification (under preparation).

Languages: The working languages of the European Union.

Consulting and support: Training.

Fees: N.A.

Selected national standards organizations

Topics covered: The many subjects covered always include wastewater management.

Description: National standards have been established. They are gradually translated into European Standards as described in Section 6.6.4.

Format: National Standards, guidelines, handbooks.

Languages: The national languages but selectively English and French.

Consulting and support: Training.

Fees: N.A.

France

Organization: Association Francaise de Normalisation (AFNOR)
Address: Tour Europe, F-92049 Paris La Defense
Telephone: +33 142 91 55 55
Fax: +33 142 91 56 56
Email: Webmaster@email.afnor.fr
Internet: www.afnor.fr/

Germany

Organization: Deutsches Institut fuer Normung DIN)
Address: Burggrafenstr. 6, D-10787 Berlin
Telephone: +49 30 26 01 0
Fax: +49 30 01 12 31
Email: Postmaster@din.de
Internet: www.din.de/

Italy

Organization: Ente Nazionale Italiano di Unificazione (UNI)

Address: Via Battistotti Sassi 11b, I-20133 Milano, MI
Telephone: +390 2 70 02 41
Fax: +390 2 70 10 61 06
Email: uni@uni.unicei.it
Internet: www.uniei.it/

Portugal

Organization: Instituto Portugues da Qualidade (IPQ)
Address: Rua Antonie Giao 2, P-2829-513 Caparice
Telephone: +351 1 294 81 00
Fax: +351 1 294 82 22
Email: ipq@mail.ipq.pt
Internet: www.ipq.pt/

Spain

Organization: Asociacion Espanola de Normalizacion y Certificacion (AENOR)
Address: Genoa 6, E-28004 Madrid
Telephone: +34 91 432 60 00
Fax: +34 91 310 40 32
Email: Info@aenor.es
Internet: www.aenor.es/

United Kingdom

Organization: British Standards Institution (BSI)
Address: 389 Chiswick High Road, LOndon W4 4AL
Telephone: +44 181 996 90 00
Fax: +44 181 996 74 00
Email: info@bsi.org.uk
Internet: www.bsi.org.uk/

6.10.6 Institutions of the European Union

Directorate-General DG XI: Environment, Nuclear Safety and Civil Protection

Address: Rue de la Loi 200, B-1049 Bruxelles, Belgium
Telephone: +322 296 11 70
Fax:
Email: dxxi@dg11.cec.be
Internet: http://europa.eu.int/comm/dg11/

Topics covered: Environment, including wastewater management, water pollution.

Description: The Directorate-General is organizational entity responsible for all matters of the environment within the administration of the European Union.

Format: Directives and other forms of legislative and regulatory documents.

Languages: The working languages of the European Union.

Consulting and support: N.A.

Fees: N.A.

European Environment Agency (EEA)

Address: 6, Kongens Nytorv, Copenhagaen K DK-1050, Denmark
Telephone: +45 3336 7100
Fax: +45 3336 7199
Email: eea@eea.eu.int
Internet: www.eea.eu.int/

Topics covered: All technical subjects concerning the environment in Europe, including wastewater.

Description: The EEA is the technical arm of the Directorate-General for Environment, Nuclear Safety and Civil Protection of the European Commission.

Format: Reports, publications, data.

Languages: The working languages of the European Union.

Consulting and support: Training.

Fees: N.A.

Topic Center Inland Water

Address: Water Research Centre, Henley Rd. Medmenham, Marlow, Bucks, SL7 2HD, UK
Telephone: +44 1491 571 531
Fax: +44 1491 579 094
Email: Tlack@etc-iw.eionet.eu.int
Internet: http://etc-iw.eionet.eu.int/
Topics covered: Inland waters, water pollution, wastewater and stormwater management.

Description: The UK Water Research Centre (WRc) acts as the Topic Center of the EEA on the subject of inland water. It keeps data bases, prepares reports and collaborates with national focal points in the collection of information.

Format: Reports, studies, data.

Languages: English and French.

Consulting and support: Training.

Fees. N.A.

Statistical Office of the European Commission (EUROSTAT)

(see Section 6.10.5)

6.10.7 National environment agencies (selected countries)

Description: The agencies listed below are the national administrations and/or coordination bodies responsible for matters concerning the environment. Their mandates and programs vary widely though most of them have some degree of legislative authority. They monitor the state of the environment, support research and investigations, provide public and technical information, and undertake training. In some cases, the agencies include technical centres and documentation services.

Topics: Matters of the environment, including wastewater and stormwater management in most cases.

Format: Reports, studies, reviews, publications.

Languages: The national languages and, selectively, English and French.

Consulting and support: N.A. as concerns matters of interest to the developing countries.
Fees: N.A.

Austria
Organization: Federal Minister of Environment, Youth and Family Affairs
Address: Stubenbastei 5, A-1010 Vienna
Telephone: +43 1 515 220
Fax: +43 1 515 22 5000

Belgium
Organization: Ministre de la Securité, de l'Intégration Sociale et Environnement
Address: Bd de Galilée 5, B-1210 Bruxelles
Telephone: +322 210 19 11
Fax: +322 217 3328

Denmark
Country: Denmark
Organization: Minister of Environment & Energy
Address: Hoejbro Plads 4, DE-1200 Copenhagen K
Telephone: +45 33 92 76 00
Fax: +45 33 32 22 27

Finland
Organization: Minister of Environment
Address: P.O.Box 380 (Kasarnikatu 25), FL-00131 Helsinki
Telephone: +358 9 199 11 57817
Fax: +358 9 199 9545

France
Organization: Ministre de l'Environnement
Address: 20, Avenue de Ségur, F-75302 Paris 07 SP
Telephone: +33 1 42 19 20 21
Fax: +33 1 42 19 11 22

Germany
Organization: Federal Minister for the Environment, Nature Conservation and Nuclear Safety
Address: Kennedyallee 5, D-53175 Bonn
Telephone: +49 228 305 20 03
Fax: +49 228 305 32 25

Greece
Organization: Minister of Environment, Physical Planning and Public Works
Address: Amaliados 17, GR-11523 Athens
Telephone: +301 643 14 61 to 9
Fax: +301 645 17 93

Italy
Organization: Minister of Environment
Address: Piazza Venezia 11, I-00187 Rome
Telephone: +39 06 5722 55 02
Fax: +39 06 7528 85

Luxembourg
Organization: Ministre de l'Environnement
Address: 18, montée de la Petrusse, L-2918 Luxembourg
Telephone: +352 478 68 06
Fax: +352 40 04 10

The Netherlands
Organization: Minister of Housing, Spatial Planning and the Environment
Address: Rinstraat 8, NL-2515 XP The Hague
Telephone: +31 70 339 34.04 – 339 39 39
Fax: +31 70 339 13 50

Norway
Organization: Minister of Environment
Address: Box 8013 Dep., N- 0030 Oslo
Telephone: +47 22 24 90 90
Fax: +47 22 24 95 60

Portugal
Organization: Ministerio do Ambiente e Recursos Naturais
Address: 51, Rua so Seculo, PT-1200 Lisbon
Telephone: +351 1 323 15 00, 346 28 70
Fax: +351 1 347 93 41

Spain
Organization: Ministro de Medio Ambiente

Address: Paseo de la Castellana 67, E-28046 Madrid
Telephone: +34 91 597 70 00
Fax: +34 91 597 64 36

Sweden
Organization: Minister of the Environment
Address: S-10333 Stockholm
Telephone: +46 8 763 10 00
Fax: +46 8 21 96 28

Switzerland
Organization: Département fédéral de l'environnement, des transports, de l□énergie et de la communication
Address: Palais Fédéral Nord, CH-3003 Bern
Telephone: +41 322 41 11
Fax: +41 311 95 76

United Kingdom
Organization: Minister of the Environment
Address: 2, Marsham Street, London, SW1P 3EB
Telephone: +44 20 7944 3000

6.10.8 Other sources of interest

UNEP Regional Office for Europe (ROE)

Address: 15 chemin des Anemones, CH-1219 Chatelain, Switzerland
Telephone: +41 22 917 82 00
Fax: +41 22 797 34 20

Description: ROE is the regional office of the United Nations Environment Programme (UNEP).
Topics covered: Environment in Europe.
Format: Reports, documents, general information.
Languages: English and French.
Consulting and support: Advisory services to national governments.
Fees: N.A.

UN Economic Commission for Europe (UN/ECE), Environment and Human Settlements Division

Address: Palais des Nations , CH-1211 Geneva, Switzerland
Telephone: +41 22 917 23 70
Fax: +41 22 917 01 23
Email: kaj.barlund@unece.org

Topics covered: Economics in Europe, environmental protection, water pollution. wastewater management, including wastewater statistics.
Description: In cooperation with Member States, the ECE develops international agreements on transboundary pollution of waters.
Format: Reports, documents and general information.
Languages: English and French.
Consultation and support: Advisory services to governments.
Fees: N.A.

WHO Regional Office for Europe

Address: Scherfigsvej 8, DK-2100 Copenhagen, Denmark
Telephone: +45 39 17 13 47
Fax: +45 39 17 18 78
Email: postmaster@who.dk

Topics covered: Health in Europe, including environmental health (including water pollution).
Description: The office is the regional entity of WHO and cooperates with Member States in the field of health and environmental health.
Format: Reports, documents, general information, training, proceedings etc.
Languages: English and French.
Consulting and support: Advisory services to governments.
Fees: N.A.

Environment Directorate of OECD

Address: 2, rue Andre Pascal, F-75775 Paris Cedex 16, France
Telephone: +33 145 24 93 02
Fax: +33 144 30 63 99
Email: brendan.gillespie@oecd.org

Description: The Directorate is the environmental arm of the Organization for Econo9mic Co-operation and Development (OECD). It serves the OECD´s Environment Committee and undertakes studies and surveys in cooperation with OECD members.
Format: Reports, reviews, publications, training.
Languages: English and French.
Consulting and support: Advisory services to governments.
Fees: N.A.

EUREAU

Address: Rue Colonel Bourg 127, BE-1140 Bruxelles, Belgium
Telephone: +32 2 706 40 80
Fax: +32 2 706 40 81
Email: Eureau@skynet.be

Topics covered: Water supply and wastewater.
Description: EUREAU has been acting as a promotional organization vis-à-vis the European Union in the field of water supply for several year.

It has merged with the European Waste Water Group in 1998 and will also represent matters of wastewater and stormwater management.
Format: Studies and reports, seminars, training.
Languages: English and French.
Consulting and support: Advising the European Union, national governments, and national water and wastewater associations.
Fees: N.A.

6.11 Case studies (Topic k)

6.11.1 Case study 1: real time control of urban drainage and sewerage system in Bolton, UK*

The existing Bolton Town Centre sewer system now serves a population of 90 000 in an area of some 4 500 Ha, or approximately one third of the total Bolton population. The network is comprised largely of brick sewers which were constructed between 1870 and 1930 to take both foul and surface water. The Croal Valley/Middlebrook trunk sewer was initially constructed in the 1930s to intercept the direct discharges and thus reduce pollution of the Middlebrook and River Croal. However to minimize the size and cost of this sewer numerous overflows were retained to restrict the flows passed to the newly constructed sewer. Following development of Bolton as a town with a population rising to 250 000, river pollution of the Croal caused by the 42 crude overflows has gradually worsened and condition have deteriorated to an unacceptable level. In a study undertaken in 1987, possible solution were identified to rationalize the number of overflows in the catchment and significantly reduce pollution.

Two off-line retention tanks with a capacity of respectively 9000 and 2000 cu. m were built and completed in 1992. Two more tanks were commenced in 1992, one being a 1250 cu. m on-line oversized gravity sewer, the other a 10 000 cu. m off-line sump style tank from which a pump returns the sewage on cessation of the storm. This construction programme has been designed to alleviate flooding and pollution. The next step was to rationalize the operation of the scheme so that:

- the flow will be accommodated in the downstream sewers;
- no downstream flooding will occur;
- no spillage takes place at downstream overflows;
- the receiving treatment plants will be able to handle the additional load;
- and sewage will not stand in any of the tank for more than 24 hours, taking into account that no sewage can be passed from tank to tank.

The overall objective of the scheme was to maximize the use of the storage facilities during storm events to eliminate flooding, minimize pollution to local rivers and to optimize the use of the treatment works.

The system for controlling the operation involves the adaptation of existing telemetry equipment collecting data on a daily basis from ten raingauges located around Bolton together with sewers depth monitors, major overflows and treatment works. This links to a second system providing "alarm data" required for reactive maintenance of small pumping stations and to monitors installed at the above-mentioned tanks. Other monitors cover remote pinch points on the trunk sewer. The system collate all data at a single System Control And Data Acquisition (SCADA) Masterstation based at the receiving treatment works. The control computer interfaces with the computer to extract relevant data for simulation. Simulation and

* Excerpted from: Sharman , B.J. & Tidswell, R.G., 1993

optimization of the system in real time is undertaken using MOUSE ON-LINE and control decisions sent back to the SCADA to enable activation on site.

MOUSE ON-LINE is based on a modular design with two blackboards, an external to exchange information with SCADA and an internal for the exchange of information between the modules constituting MOUSE ON-LINE. The main modules are:

- The rain forecasting module. Based on on-line rain measurements and a description of a growth and decay time profile for the rain, a rain forecast is computed.
- The runoff forecasting module. Based on the rain forecast and a description of the network topography, a forecast of the sewer load is computed.
- The control module. Based on the forecasted sewer load, a control strategy is selected and the corresponding control actions set out.

The system works in three modes, viz. monitoring, forecasting and controlling. It is based on close monitoring of the performance of the tanks, treatment works and network overflows and will provided archive data of the implications of various storms and control actions. A set of criteria specify when the mode is changed. The change from monitoring to forecasting is needed when the current situation in the sewer indicates that information about the expected situation is necessary. This could be the case when the intensity of the rain or the inflow to the treatment plant or levels in overflow structures exceed biological capacity ; in this case, the system changes back to monitoring.

6.11.2 Case study 2: optimization of nutrient removal in the wastewater treatment plant Zürich-Werdhölzli, Switzerland*

The plant at Werdhölzli is the largest treatment plant in Switzerland. It handles wastewater from about 500 000 pe. A second plant receiving wastewater from the city of Zürich is located at Zürich-Glatt and handles about 100 000 pe. The plant at Glatt will cease operation by the year 2001 and the wastewater it handles now will be transferred to Werdhölzli by tunnel and the plant will be upgraded. The total volume of wastewater was 225 300 m3 per day in winter of 1997 and the total chemical oxygen demand of the primary effluent was 53 500 kg per day, and, respectively, the total Kjeldahl–load 6 410 (of which 1050 was digester supernatant), total nitrogen 4 700 and phosphorous 895 kg per day. It should be noted that the COD/N ratio shifted from 7.5 to 8.5 in the last 10 years which allows a significant improvement of the denitrification capacity. Since phosphate was banned from detergents in 1986, the phosphate load did not change significantly during that period and the slight increase of the P-load might be due to polyphosphates used in dishwashers. Simultaneously, the COD-load increased substantially due to increase discharges of industrial wastewater, enzymes used in households and grease removal tanks.

In 1986, Werdhölzli was enlarged for permanent nitrification with an average total nitrogen concentration in effluent of less the 2000 mg/m^3 at 10 °C. The initial activated sludge system operated as a partial two stage treatment with a fully aerated pre-step and consists of two lanes each having six parallel activated sludge tanks (5000 m^3 each) and six secondary clarifiers (6000 m^3 each).

Combining the flows received at the Werdhölzli and Glatt plants and, at the same time reaching high levels of nutrient removal required careful studies and the optimization of process and structural design and operation of the plant at Werdhölzli involving:

* Excerpted from: Siegrist *et al.*, 1999

Hydraulic capacity: During the 1980s and 90s, the amount of infiltration was substantially reduced. The dry weather peak flow of both plants is now about 3 cbm per second which allows a substantial reduction of storm peak flow from 9 to 6, taking into account the 40 000 m^3 stormwater tank located before the plant at Werdhölzli which reduces the overflow of untreated stormwater to less than 0.5% of the total annual wastewater flow. The existing aeration tanks can, thus handle the inflow from Glatt, even with the provision of anoxic zones (see below) and if the concentration of activated sludge is increased by some 50%. Reserve capacity is still 10%.

Installation of anoxic zones and reduction of oxygen input during primary treatment: During a pilot operation, anoxic zones of 28 vol% were installed in two parallel aeration tanks in one of the lanes at Werdhölzli, dived into two compartments with a volume of 700 m^3. This reduced the nitrogen concentration in the secondary effluent by about 40% to an average of 10 g nitrate-nitrogen per cbm. Simultaneously, the energy for oxygenation was reduced by about 15%. Average effluent alkalinity increased by about 0.6 mM to above 3 mM which reduces corrosion of cement and improves nitrification. In the light of these positive results, anoxic zones were also installed in the remaining lanes. Additional measures to improve denitrification included:

- Improved sludge blanket by a reduction of scraper speed in the secondary clarifiers by 25 to 50%.
- Reduction of oxygen input and degradation of readily degradable COD during primary treatment by reducing air flow in the grit removal tank, conducting excess sludge directly into the primary clarifiers, and reducing weir height of the primary clarifiers.
- Reduction of oxygen input in anoxic zones by more frequent controls of return sludge pumps.

Digester supernatant treatment: A pilot study is under way to treat digester supernatant with anaerobic ammonium oxidation. In the process, half of the ammonium will be oxidized to nitrite and the remaining ammonium with the nitrite in the anoxic reactor. No organic carbon is required for denitrification; the costs of chemical and energy will be lower than for conventional nitrification and denitrification of the supernatant. If the pilot study is successful, the overall nitrogen removal of the plant will be 75%.

Internal recirculation: Recirculation from the last section of the aeration tanks to the first or second compartments of the anoxic zones is also under study with several objectives in mind:

- To cope with occasionally high concentrations of COD and resulting partially anaerobic conditions in the anoxic zones.
- To supply sufficient nitrate to the anoxic zones when concentrated organic industrial wastewater is to be handled by the plant.
- To enhance phosphorous removal.

Enhanced biological phosphorous removal: If the treatment of digester supernatant can be successfully installed, the first anoxic compartment could be kept in anaerobic conditions which would enhance biological removal of phosphorous.

6.11.3 Case study 3: the reuse of treated effluent in Spain*

Spain is one of the European countries where water resources are scarce, especially along the Mediterranean cost South of Barcelona and on the Balearan and Canaries islands. Direct and planned reuse of effluent is considered a valid option for augmenting the natural resource

* Excerpted from: Catalinas & Ortega, 1998

though a number of constraints have limited the extent of reuse in the past, among them the degree of treatment of the wastewater and the cost of water conveyance from STPs to the point of use. On the other hand, the following benefits of the reuse of effluent are acknowledged:

- Treated effluent is a valid incremental resource, especially where without reuse, it is discharged into the sea.
- Treated effluent is a valid source for reuse within human settlements where strict criteria will not apply such as those for the quality of drinking water.
- Reduction of water pollution.
- Reduction of energy consumption when reuse is intended in the vicinity of STPs.
- Recovery of nutrient contained in treated effluent.
- Reuse as a major water resource in arid zones, such as on the Balearan and Canaries archipelagoes.

In this context, it is recognized that the amount of treated effluent will increase considerably when the implementation of EU directive 91/271 concerning the treatment of urban wastewater is achieved in 2005 (Section 6.3). At that time, a volume of more than 350 000 m^3 will be produced annually of which perhaps one third may be feasibly available for reuse by the year 2012. The major consumer will always be agriculture but other uses are also potentially valid, i.e.:

- Municipal use, e.g. for the irrigation of parks, fire fighting, street cleansing.
- Recreational use, e.g.: irrigation of golf courses, and artificial lakes.
- Recharge of aquifers, combating seawater intrusion and other "ecological" uses.
- Industrial use, e.g.: flushing and cleaning of materials or use as cooling water.

The need to assure a safe water quality is fully understood and is a major factor in the planning of the reuse of effluent. Strict quality criteria are still needed though it is recognized that in any case, wastewater treatment will involve tertiary technology, especially filtration, microfiltration, physico-chemical processes, disinfection, and/or desalination whenever exposure of people to the treated effluent is possible.

El Cedex, an independent research and development organization under the Ministries of Education, and Environment, has established a data base on the reuse of effluent containing information on the schemes for reuse, the volume of effluent used, application of the effluent, and wastewater treatment provided. There are currently 124 schemes in operation which use a volume of 2 320 000 m^3 treated effluent annually. The data base of El Cedex provides detailed information on 41 of the schemes which use 2 080 800 m^3 annually or 89% of the total volume reused. Agriculture is the main user with 88.7%. The total volume of effluent is used as follows:

Table 6.26: Reuse of treated effluent in Spain

Type of reuse	Volume 1000 m^3/year	Percentage
Agriculture	2057	88.7
Municipal	49	2.1
Recreational	1 49	6.4
Industrial	25	1.1

Ecological	40	4.7

Source: Catalinas & Ortega, 19XX

The 41 schemes referred to above vary considerably:

- 25 schemes use effluent solely for agricultural purposes. For all of these, the wastewater is treated by the activated sludge process. It should be noted, however, that tertiary treatment of wastewater is now considered essential prior to the reuse of effluent for the irrigation of certain crops (see below).
- 8 schemes serve agriculture and golfing. Only three of these treat wastewater by activated sludge followed by tertiary treatment by filtration and chlorination or ozonization while the three remaining use activated sludge.
- 4 schemes serve municipal purposes and in a few cases, are combined with agricultural use. All of these apply tertiary treatment in addition to activated sludge.
- Of the remaining 4 schemes, 3 use the effluent for "ecological" purposes and one for cooling. They apply the activated sludge process.

The above information confirms that in the sample of 41 schemes, tertiary treatment of the wastewater is practiced whenever people may have contact with the treated effluent. For the future, however, tertiary treatment is also considered essential as follows although legislation is not yet in place:

- Tertiary treatment plus disinfection for irrigation of ornamental plants in recreational areas with potential contact by people and products eaten raw. In these cases, faecal coliform (MPN) less than 10/100ml and residual chlorine higher than 0.6 and 0.5 mg/l, respectively (after 30 minutes).
- Secondary treatment plus disinfection for the irrigation of cereals, fruit trees etc. with faecal coliform less than 500/100ml and 200/100 ml, and residual chlorine higher than 0.1 and 0.3 mg/l, respectively.
- Tertiary or secondary treatment prior to the reuse for recreational areas with/without contact of the public with the effluent, and faecal coliform less than 200/100ml and 10000/100ml, respectively.
- For cooling, faecal coliform less than 200/100ml and 10000/100ml for, respectively, closed and open systems.

The lack of legislation concerning quality standards for the reuse of effluent is a major problem which constrains the planning of additional schemes for reuse. It has been proposed therefore, the European Union establish a Directive. Other constraining factors include the following:

- The absence of a comprehensive water resources plan with a clear indication of priority areas where the reuse of effluent would be promoted.
- The logistical and financial problems associated with the construction of many STPs with tertiary treatment which would be required.

Nevertheless, 8 new schemes are under construction and for 7 more, tendering is under way. At least 20 more schemes are being planned. Some of those under construction are big schemes with an annual volume of effluent reused of up to 150 000 m^3 per year and most are for agricultural irrigation. The scheme under construction for Madrid will reuse 90 000 m^3 per year for municipal greenery. Many of the smaller schemes will reuse effluent for parks and golfings.

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7. Europe (East)

7.0 Introduction

The countries of Central and Eastern Europe are currently in transition. Transition means the recovery process from the breakdown of the state-controlled economies after the political changes in the beginning of the 1990s to market-oriented economies. Now, after 10 years of transition, new legislation is approaching market economy requirements. Privatisation of small and medium enterprises and of agricultural land is developing, and realistic environmental taxes and economic instruments are being legislated to protect the environment. However, in all transition countries the economy has priority over the environment, so there are only limited financial resources available for investment, modernisation or reconstruction of environmental protection facilities. In some countries, in order to keep jobs from disappearing, parts of industry and agriculture are still subsidised by governments. In short, there are big differences between single countries or country groups of this region concerning economic performances, social achievements and the realisation of environmental protection measures.

In this overview, the countries of Central and Eastern Europe are subdivided into three different groups (see Table 7.1):

- the 10 Accession Countries (AC); transition countries which are on the way to become members of the European Union in the future.
- other transition countries (Balkan countries, except Accession Countries and countries of the former Soviet Union),
- some of the European countries of the Commonwealth of Independent States (CIS)- the former Soviet Union Republics- Belarus, Republic of Moldova, Russian Federation, and Ukraine. During the preparation of the overview, no information was available regarding the three Caucasian countries Armenia, Azerbaijan and Georgia.

In March 1998, the European Union (EU) handed over to ten transition countries (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia) individual Accession Partnership Agreements (APAs), which set out for each country the conditions for the granting of EU pre-accession aid and criteria for assessing progress made in aligning their economies and legislation with the EU's (EIS, 1998). For five of these countries (Czech Republic, Estonia, Hungary, Poland and Slovenia) special talks with the EU are ongoing concerning an accession in the near future. An important prerequisite for technical and financial assistance by the EU is the alignment to the EU environmental standards, specially in the areas of water and energy. At present, none of the Accession Countries will be able to achieve full compliance with the environmental requirements in the short to medium term (EIS, 1998).

In the wastewater sector, the most important EU requirement is the Urban Waste Water Treatment Directive (UWWTD). The objective of the Directive is to protect the environment from adverse effects of discharges of urban wastewater and of wastewater from industrial sectors. The implementation of the Directive in the Accession Countries could result, with high effort on sewerage development and wastewater treatment with nutrient removal, in a two-thirds reduction in organic matter load and a 40-50% reduction of nutrients input. This would potentially reduce the nitrate and phosphate loading to both the Baltic and Black Seas by around 15-30 %, but would increase the sludge production and the costs by about 9 billion Euros (EEA, 1998). The three scenarios for the Accession Countries are presented in section 7.3.

Table 7.1: Overview of the transition countries of Central and Eastern Europe by groups

Country	*Total area (in km^2)	**Population (10^3)
	Accession Countries	
Bulgaria	110 910	8 336
Czech Republic	79 000	10 282
Estonia	45 226	1 429
Hungary	93 030	10 116
Latvia	64 589	2 424
Lithuania	65 301	3 694
Poland	312 680	38 718
Romania	237 500	22 474
Slovakia	48 845	5 377
Slovenia	20 251	1 993
	Other Transition Countries	
Albania	28 750	3 119
Bosnia and Herzegovina	51 129	3 675
Croatia	87 600	4 481
The Former Yugoslav Republic of Macedonia	25 713	1 999
Yugoslavia, Federal Republic	102 000	10 635
	Commonwealth of Independent States	
Belarus	207 600	10 315
Moldova, Republic of	33 700	4 378
Russian Federation	17 075 400	147 434
Ukraine	604 000	50 861

* Data of the total area are taken from the "The World Factbook", 1999
** The population data are gathered from the UN Population Estimates and Projections, 1998.

The wastewater management situation in most of the other transition countries, including the countries of the former Soviet Union, is even more severe, because of lack of technical, financial and sometimes institutional support. Quite often, the limited financial sources are used for stabilising the water supply system rather than for wastewater management. Most sewer systems are old, overloaded and leaking. Inflows of groundwater, diluting wastewater and resulting in overloading treatment plants are very common. Most of the treatment plants have operational problems and low levels of efficiency.

In all transition countries, both, drinking water supply and wastewater management have top priority in environmental policy. Particularly in the economically most advanced Accession Countries, as well as e.g. in Croatia and in parts of Russia (the Moscow region) investments in wastewater treatment have been rising remarkably. In the other transition countries these investments depend very much on the current economic and financial situation and on the national/local priorities given to wastewater management. Often only hot spots in collection and treatment can be covered by national budgets and/or with international support. New solutions for financing national wastewater management and water pollution control are necessary to meet the challenges today and in the future.

In order to foster the economic development and legislative basis of transition countries, the European Union and other international organisations and banks (e.g. UNDP, World Bank, the EBRD) help to foster bilateral agreements between countries. Furthermore these organisations participate in this transition process through a number of different technical and financial projects, credits and loans. The European Union for example, is supporting the Accession Countries and the other transition countries through investment programs (i.e. PHARE and TACIS projects). The programs are targeted to hotspots or specialised tasks (monitoring, construction of environmental protection facilities etc.). Here, special attention has to be devoted to long-term sustainability of these projects in order to assure the financing and operation/maintenance of the projects in the long run.

The role of the European Union and other international institutions in financing the enormous demands in wastewater management of the transition countries can only be minor, but should be catalytic. Resource mobilisation has to be more effectively integrated into the national financing strategies of the transition countries themselves, which should include the national private sector, regional and local investments of the governments, taxes, fees and charges. The responsibility of financing wastewater management investments should be increasingly transferred to polluters and consumers of water through the implementation and strict enforcement of for example the polluter-pays-principle and water service taxes.

In this regional overview, most of the statistics and information of the transition countries are derived from the UN/ECE and OECD Environmental Performance Reviews (EPR), which describe the state of environment and the new environmental policy as well as achievements of the countries. The National Environmental Action Plans (NEAP) were taken into consideration for the preparation of the EPRs. At present, 7 EPRs of transition countries have been published by UN/ECE (Croatia, Estonia, Latvia, Lithuania, Republic of Moldova, Slovenia and Ukraine) and the OECD has published one for Bulgaria.

The UN/ECE International Environmental Data System (IEDS) was used for gathering statistical data, as well as national environmental yearbooks, and the Dobrish Reports of 1995 and 1998 of the European Environmental Agency in Copenhagen. These data were transmitted and checked by the countries themselves, but unfortunately, there are still no international harmonised definitions of terms which limits the comparability of the data.

For the Accession Countries, most information was taken from different publications put together by the European Union, DG XI and IA, or their releases on the internet (see references).

7.1 Wastewater characteristics (Topic a)

7.1.1 Wastewater generation

After the political breakdown of the centrally-planned economies in the beginning of the 1990s wastewater generation in both accession countries and other transition countries of Central and Eastern Europe, has considerably declined. The available data and information about wastewater generation show that the decline in generation has continued until 1995 and later. The introduction of new, more efficient technology in industry, low consumption levels and water pricing in some countries might also be responsible for a decline in both, industrial and municipal wastewater generation. Therefore, depending on the political and economical situation in the different countries, a slight increase in economic activities in the last few years did not necessarily lead to an increase in wastewater generation. For example, in Poland wastewater generation decreased by 0.2% in the period 1995-1997 (Polish Statistical Yearbook, 1998); but in Croatia the total generation of wastewater increased by about 8% during the same time period (EPR, 1999).

Quite often, measurements of wastewater quantity generated by different pollution sources and their material composition are not fully conducted by municipalities in transition countries. Reasons might be insufficient laboratory capacities and equipment, unclear ownership of treatment plants and no real enforcement of legislation to meet national effluent standards. Often polluters, like industrial enterprises, do not regularly monitor their effluents.

Because of different national wastewater management strategies and definitions of wastewater generation a comparison of data between countries is difficult. Some countries include cooling, mining and/or precipitation-waters in their definition of wastewater generation. Moreover, not all countries submitted information divided into municipal, industrial and agricultural wastewater. Sometimes industrial and agricultural wastewaters are combined.

Total wastewater, as it is used in the following tables 7.2 and 7.3, covers municipal, industrial and agricultural wastewater.

Municipal wastewater includes wastewater from household connections, small enterprises and sometimes stormwater runoff. Declining population numbers combined with low consumption levels and the breakdown of many small and middle-sized enterprises connected to the municipal wastewater system show impact on the generation of municipal wastewater. According to the available data, in most transition countries the generation of municipal wastewater decreased on average by about 20% in the period between 1990 and 1995. After 1995 in most countries wastewater generation is still decreasing but only slightly. The introduction of water pricing in some Accession countries, i.e. Poland and Czech Republic, has led to a more rational water use and decreased the amount of municipal wastewater. In countries where drinking water is still heavily subsidised by the government, water demand and wastewater generation are still high (i.e. Bulgaria, Romania, most CIS). Of course there are also large regional differences in each country, not only between rural and urban areas, but also between smaller and bigger towns, and towns with separate stormwater systems.

Industrial wastewater includes industrial effluents (with or without pre-treatment), but sometimes also cooling water from energy production and mining water. Industrial wastewater generation has considerably diminished after the political changes in the beginning of the 90s. According to the available data, in many transition countries like Bulgaria, Czech Republic, the Baltic States and Romania the decline in industrial wastewater was between 30-45% in the period between 1990 and 1995. In Hungary and Poland the decline was only between 7-10% in the given period. The slight improvement in wastewater quantity is mostly based on reduction in the production process, and not always because of improvements or constructions of effective treatment facilities.

In Estonia, for example, the water use in industry has fallen over 56% in the period between 1991-94, similar to the wastewater generation. This has been caused by the structural reforms and by recession. The activities food industry or pulp and paper has decreased considerably. In recent years, some of this industry has restarted their activities, often without new environmental investments. For example, drainage water pumped out of oil-shale mines and pits, which contains sulphates, nitrates and suspended solids, is discharged directly into water bodies (EPR, 1996).

Table 7.2: Total generation of wastewater in accession, other transition countries and countries of the Commonwealth of Independent States (CIS), (million m^3/year)

Country	Year	Total	Agriculture	Industry	Municipal
Accession countries					
Bulgaria	1990	1873	27	1026	820
	1995	1401	41	599	760
Czech Republic*	1990	858		405	453
	1995	612		278	334
Estonia*	1990	3260	290	2840	130
	1995	1849	190	1555	104
Hungary	1990	974	5	268	701
	1995	828	22	250	555
Latvia	1990	552	136	171	245
	1995	348	56	108	184
Lithuania	1990	446	11	84	351
	1995	449 epr			
	1997	471 epr			
Poland*	1990	11368		9055	2314
	1995	9981		8129	1852
	1997	9961		8269	1692
Romania	1991	7852 ?	165	5123 ?	2561 ?
	1995	5268 ?	93	3072 ?	2103 ?
Slovakia	1990	1209			
Slovenia*	1990	292		155	137
	1994	237		96	141
Other transition countries					
Bosnia and Herzegovina	1989			3465.5	167.3
Croatia*	1990	315 epr		204	112
	1995	268 epr		146	122
	1997	289 epr		155	134
FYR Macedonia	1990	249			
FR Yugoslavia	1990			6318	547.5
CIS					
Rep.of Moldova	1990	2759	169	2319	271
	1995	1381		17	159
Russian Federation	1990	78019	14363	49774	13133
	1992	73339	14909	44294	13421
Ukraine	1995	14981	2686	8234	59.9
	1996	13998	2387	7613	57.5

Source: UN/ECE, IEDS; Polish Statistical Yearbook, 1998;

Czech Republic: In the industry data agriculture data are included.
Estonia: Industrial wastewater includes wastewater from energy production, stormwater and mining water. Agricultural wastewater includes fish farming.
Poland: Without agricultural wastewater, which was estimated as $1km^3$ in 1990.
Slovenia: There are no data for agricultural wastewater available. Industrial wastewater includes manufacturing and mining, without generation of electricity.
Croatia: Generation of industrial wastewater includes agricultural wastewater too.

Agricultural wastewater includes wastewater generated through the operation of agricultural enterprises and activities, and sometimes contaminated groundwater. Agricultural production declined significantly in most transition countries after the political changes. Most countries started with privatisation programs to size down the large state farms and co-operatives into small and medium sized farms. At present the use of fertilisers and pesticides is limited by financial factors. It is expected that soon more intensive farming systems will occur. In order to increase agricultural exports to Western Europe the development of organic farming systems is expected to grow. The accession of countries to the EU will further stimulate this process (EEA 1998a, p29). In the period of data available, the agricultural wastewater generation declined in the Baltic States, Romania, Slovenia, Moldova and Russian Federation but increased in others, like Bulgaria, Hungary, and FYRO Macedonia.

Table 7.3: Total wastewater generation in litre per day and capita for Accession countries (AC10), other transition countries and CIS

Country	Total wastewater generation (l/day/capita)		
	1990	1995	1997
AC10			
Bulgaria	589	451	
Czech Rep.	228	163	
Estonia*	6002	3404	
Hungary	258	225	
Latvia	564	376	
Lithuania	327	343	360
Poland	889	780	707
Romania	927	635	
Slovakia	630		
Slovenia	417	337	
Other transition countries			
Croatia	180	159	169
FYRO Macedonia	337		
CIS			
Rep.of Moldova*	1732	853	
Russia	1441	(for 1992) 1354	
Ukraine		793	(1996) 770

Source: Data for total generation of wastewater are from UN/ECE IEDS,
Population data are from EEA, Statistical Compendium, 1998, for 1998 from the CIA Yearbook website.
Poland: Data from the Polish Statistical Yearbook, 1998.
The data for table 7.3 are calculated from table 7.2
Note: * Estonia and Moldova: the data cover also cooling and mining waters.

7.1.2 Characteristics

It can be assumed that there is little difference in total loading discharged between EU15 (European Union Member States) and the AC10. However, the use of water per capita is considerably higher in AC10, while the quality of rain water that has to be treated is often lower because of the presence of separated sewers (e.g. Poland). Table 7.4 compares quantity (flow) and quality (concentration) of wastewater from EU 15 and AC 10 (ETC/IW, 1998). It is supposed, that the current lower wastewater concentrations in the AC 10 compared to the EU 15, which originated in the economic regression, will increase in the coming years through industrial and agricultural growth. Future treatment capacities in the AC 10 will not completely cope with increasing wastewater quantity and declining quality until the UWWTD and other directives are in full power.

In the early 1990s, the total organic pollution load from urban wastewater treatment plants for the AC 10 was for BOD_5 about 1136 kilotonnes O_2/year. The nutrient load was at the same time for total P about 69 ktonnes P/year and for total N about 334 ktonnes N/year (ETC/IW, 1998). There is little information available regarding the other transition countries.

In the European CIS countries a high percentage of the population is connected to municipal wastewater treatment plants (60-75%), but most villages discharge without treatment. Municipal wastewater treatment plants are mostly designed to reach a 60-70% reduction in BOD. However, in the early 1990s only about 60% of the installations were functioning and there is no indication that the situation has improved since then.

Table 7.4: Wastewater characteristics in the EU 15 and AC 10 countries

Parameter	EU 15	AC 10
Quantity (l/c/d)		
• Dry weather flow	117	180
• Rain water discharge	43	20
• Total quantity	184	200
Quality (mg/l)		
• COD	523	350
• BOD5	191	100
• N (Kjeldahl)	48	35
• P tot	8	6
• Suspended matter	304	117

Source: (ETC/IW, 1998)

Sometimes, the pollution discharge standards of municipal wastewater are ignored. This is due to the limited treatment capacity of most plants, causing overload, and the high pollution load of the incoming wastewater. Due to poor maintenance and the poor technical state of installations, overloading and even complete breakdown, the reconstruction or extension of existing plants is unsatisfactory or has been completely abandoned for the time being.

Many industrial enterprises are connected to municipal treatment plants and most of them are required to have pre-treatment facilities. However, industrial wastewater plants that were constructed in past years are either not in use or not well maintained. The absence of detoxifying pre-treatment of wastewater from i.e. metal finishing / galvanising enterprises leads to an excess of heavy metals in municipal treatment plants, undermining biological treatment. It is assumed, that the situation has not greatly improved over the last few years, although the continuing recession accounts for some reduction in industrial wastewater generation. Furthermore, treatment efficiency and other investment–dependent indicators have also deteriorated further.

In Croatia, the bulk of generated wastewater is treated only mechanically (primary treatment) (81%); which means poor performance yields, except for suspended solids, and a poor effect on dissolved pollution. About 6% is biologically treated and 13% are combined treated. There are no data available for the pollution load, despite existing monitoring systems. The reduction in pollution load is estimated at around 25% of what is treated. Since wastewater treatment has been a priority for the past several years, many municipalities have built treatment facilities, but their operation is fraught with difficulties. Most municipalities which borrowed to finance 50% of the building costs, cannot cover the loans and so cannot operate and maintain the plants properly. The result is often, that they bypass their empty facilities and discharge their wastewater untreated. At the same time, new projects are designed and partly financed by the national water agency to equip urban settlements (EPR, 1999).

7.2 Collection and transfer (Topic b)

In the 10 Accession countries wastewater from 105 million persons is produced annually. Approximately 60% of the total population of the AC10 is connected to sewers and about 50% is connected to wastewater treatment plants (for comparison: in EU around 90% are connected to sewers and about 70% to wastewater treatment plants). In the AC 10, 42% of the wastewater receives treatment before being discharged into surface waters, with most wastewater receiving secondary treatment.

The European Urban Waste Water Treatment Directive (UWWTD), which is an important target for the AC10 to meet European norms and standards (see also 7.3 Treatment), places an obligation on member countries (and future member countries=AC10) to provide collection systems and secondary treatment (biological) for all agglomerations of more than 2000 population equivalents when discharging into freshwater, and all agglomerations of more than 10 000 p.e. discharging into coastal waters. For smaller agglomerations, which are equipped with a collection system the treated discharge has to meet the relevant quality objectives. At present, these objectives are far from being reached in the near future by the AC10. Three possible scenarios were introduced by the European Environment Agency, describing how the AC10 might approach the objectives set out by the UWWDT over the coming years. The 3 scenarios are presented in 7.3 Treatment.

In the European CIS, according to the available data, about 60-70% of the population is connected to treatment plants. In the other transition countries i.e. the Balkan States, a much smaller percentage of the population is connected to sewers and also to treatment plants. There are no data available on the amount of wastewater receiving secondary or even advanced treatment and the quality of the treated wastewater. However, the largest part of the sewage network is quite old, badly maintained and leaks. That leads to groundwater contamination on the one hand and to dilution of wastewater through penetrating groundwater, which increases the wastewater volume in treatment plants on the other hand.

With the general decentralisation of water management, investments as well as operation and maintenance of networks and treatment plants are now carried out at local levels. So at the municipal level basic, sound systems are required, if both construction and operation are not privatised. In all transition countries, many municipalities try to improve their wastewater collection and treatment. However, quite often adequate water supply has priority over wastewater treatment and the limited financial sources are not always strengthened by the government or other national or international sources. Quite often municipalities cannot afford to take out loans to continue constructions or modernisation of treatment facilities.

According to the available data (IEDS; EPR's; ETC/IW, 1998; EEAc, 1998), in the Baltic States, Poland and the Czech Republic more than 70% of the population is served by sewers, which also includes parts of the rural population. The wastewater collected in sewers is not necessarily connected to treatment plants. It is partly discharged directly into surface waters, for example through outfalls into seas, or around cities into rivers. About 50 % of the population in the AC10 is connected to wastewater treatment plants. There are large differences between countries. The degree of connection to treatment plants for the three Baltic countries is high, but this does not necessarily mean that the incoming wastewater is sufficiently treated. In Czech Republic, Poland, Slovakia on average half of the population was connected to treatment plants in 1995. Through investments made in the meantime one can suppose that there are more people connected today. For example, in Poland an increase of over 20% is indicated in the period 1990-97 (Polish Stat. Yearbook, 1998).

Table 7.5 shows the population connected to public sewage systems and to wastewater treatment plants for the 10 Accession countries, transition countries and CIS.

Table 7.5: Population connected to public sewage systems and to wastewater treatment plants (in %)

Country	Population connected to sewerage systems		Population connected to treatment plants		Treatment plants with at least secondary treatment *
	1990	**1995**	**1990**	**1995**	**Early 1990's**
AC10					
Bulgaria	66	67	35	35 (1993)	34
Czech Rep.	72	73	50	56	52
Estonia	75	77			37
Hungary		52	31	32	28
Latvia		73	69	63 (1997)	51
Lithuania		72			29
Poland		82	34	47 (1997)	32
Romania		47	22		29
Slovakia	51	58		48	45
Slovenia		44			15
Other Transition countries					
FR Yugoslavia**		35			
Croatia		35 epr			
CIS					
Belarus			65	70	100***
Rep. of Moldova			56	70	100***
Russian Federation			55		100***
Ukraine			52	60	100***

Sources: EEA c,1998; EEA, 1995; UN/ECE IEDS; Polish Statistical Yearbook 1998.
* Data from EEA/ETC/IW, 1998
** Data from WSSCC, 1997
*** In the former Soviet Union all municipal treatment plants have been designed and constructed for secondary treatment. That does not necessarily mean, that all these plants are still in operation, or that they treat the wastewater until national standards.
Note: In the transition countries available, a slight increase of the amount of people connected between 1990-1995 took place, despite the economic recession.

In the other transition countries, representing a population of at least 255.5 million people, of which about 231.5 million live alone in the CIS countries (European part only), the picture is quite different. According to the available data, in the European CIS countries far more than half of the population (between 60-70%) is connected to wastewater treatment plants. This figure is quite high and reflects mainly urban areas. In most rural areas wastewater is discharged untreated or insufficiently treated, with people using on site systems, usually pit latrines. Network systems and treatment plants suffer from overloading and poor maintenance. The situation in Ukraine may serve as an example.

In Ukraine, over 60% of the population is connected to municipal wastewater treatment plants, but in rural areas most wastewater is discharged untreated into surface water. In 1997, about 66% of the existing sewage network was located in urban areas. The sewage network in 1997 was about 46 000 km, of which 22% is in critical condition, 46% of the pump units need replacing and 25% of the installations in treatment plants have exceeded their technical life time (EPR, 1999). According to UN/ECE IEDS data in 1996 about 38% of the generated wastewater received treatment, of which about 40% with secondary treatment.

In Croatia (EPR, 1999) at least 35% of the population is connected to sewer systems, mainly in urban areas. After the war, the reconstruction of the water supply had priority over the sewer network. The downwards trend in the total generation of wastewater in the period 1990-1995 is followed by a slight increase after 1995. The amount of treated wastewater is low (in 1997 only 21%) but has been rising continuously since 1990. In order to support tourist industry along beaches, more than 60% of the population living on the Adriatic Sea is connected to sewer networks.

In Albania, 67% of the population was served by sewers at the end of the 1980s, including 90% of the population living in urban areas and about 50 % of the rural population (EWPCA, 1995). In Tirana, the capital, most households are connected to the sewer system. The total length of the network is 540 km. There is no regular maintenance of the network, only in cases of emergency interventions. The network is old, with extremely frequent breaks, polluting the groundwater (WSSCC, 1997).

In the FR Yugoslavia the collected wastewater comes to 20% from municipalities and to about 80% from industry. The length of the public sewage network is about 10 000 km connecting 35 % of the total population to the public sewage system. In urban areas nearly half of the population is connected (47% in 1993) (WSSCC, 1997).

Combined sewers, for waste and storm water, are the dominant network system. In general, only large cities in most transition countries have separate systems. Most of the stormwater networks discharge directly into surface water, without any treatment. Poland is an exception, here even the majority of the towns have separated systems, of which the stormwater network is mainly not connected to treatment plants.

In Romania, only larger towns have sewer networks, which are combined systems. There are only few exceptions with separate stormwater sewers in big cities along major rivers, where the stormwater is directly discharged into surface water. Smaller cities and villages are not connected to sewer systems (Rojanschi, V., 1999).

In Croatia, the typical sewer system is combined. Only few smaller towns and some bigger cities have separate systems. Industrial wastewater (about 30%) is discharged into the municipal sewage system, often without adequate pre-treatment. (EPR, 1999)

7.2.1 Collection and transfer in Romania

The evolution and development of the sewer system in Romania is closely connected to the water supply system, Table 7.6 (Rojanschi V 1999).

Table 7.6: Water supply and sewage systems in Romania

Type of human settlements		With water supply systems		With sewage systems	
		No.	%	No.	%
Large cities	262	262	100.0	261	99.6
Rural community centers	2686	1249	46.5	330	12.3
Villages	10390	1045	10.0	16	0.2

Currently, 261 large cities (without Fundulea City) and 346 villages (2.6% out of the total number) are connected to sewer networks. In Braila and Harghita counties no village has a sewage network, and Giurgiu and Ialomita counties have only one a piece. Some 47 of the largest cities, which do not have wastewater treatment plants yet (Bucharest, Braila, Craiova, Turnu Severin Tulcea, etc.) produce around 20 m^3/s of wastewater, which is directly discharged untreated into surface water. In the localities without centralised sewage systems, the wastewater will either be collected in water-tight basins with periodical emptying and transfer into wastewater treatment plants, or it will be discharged into individual absorbing drills.

In Romania, most sewer pipes or channels are made from bricks (the old ones), reinforced concrete, or different plastic material (more recent ones).

The amount of wastewater treated to meet national norms is unsatisfactory, so the sewer systems are pollution sources for the surface and ground water. The most frequent contaminants are insoluble inorganic salts and oils.

7.3 Treatment (Topic c)

7.3.1 Current situation

Most of the transition countries are still facing major problems. Because of complications in the privatisation process, it is sometimes not clear who actually owns the water works and sewage systems, so reconstruction or modernisation is still postponed. The lack of experience and lack of effective institutional and legal structures affect the decentralisation process, particularly the financing of i.e. treatment facilities.

Many industrial establishments are connected to municipal treatment plants. Connected industries are required by law to use pre-treatment facilities. Nevertheless, many of the constructed or existing industrial wastewater plants are not used, or are not well maintained.

7.3.2 Wastewater treatment in the Accession countries

In the AC 10 approximately half of all generated municipal and industrial wastewater is treated to a certain extent (Table 7.7). Mechanical treatment (primary treatment) is a simple and quite inefficient form of treatment, involving the removal of large solids through screening and sludge production through sedimentation lagoons or tanks. According to UN/ECE IEDS in the AC 10 nearly half of all treated municipal and industrial wastewater is only mechanically treated. There is a slight downwards trend in the last years through the installation of new or reconstruction of existing biological or advanced treatment plants. According to EEA data, on average municipal wastewater from 12% of the population in the AC 10 receive mechanical treatment. This percentage is less than 6% in countries like Czech and Slovak Republics, Hungary, Bulgaria and Romania in favour for biological and advanced treatment.

Biological treatment involves, in addition to mechanical treatment, biological sand-filters and constructed reedbeds, which achieve microbiological degradation of organic matter and a considerable removal of nutrients. In the AC 10 about 40% of the treated municipal and industrial wastewater receive biological treatment. There is a slight downward trend in favour of an increased advanced treatment. Advanced treatment might have different stages like coagulation and flocculation, precipitation, etc. (chemical treatment), but can also include advanced nutrient removal through nitrification/denitrification and removal of phosphorus. Unfortunately, through the given data it is not clear which kind of advanced treatment is used in the individual countries. Advanced treatment is increasing in all AC 10 countries over the period 1990-1995 and later, even if the nutrient removal efficiency is varying between the countries (Table 7.8 and Figure 7.1).

Table 7.7: Municipal wastewater treatment (% of AC10 population in the early 1990s)

	BG	CZ	EE	HU	LA	LT	PL	RO	SK	SL
Untreated	35	17	9	12	12	12	23	12	8	13
Mechanical	0	4	27	5	10	32	10	6	5	16
Biological	34	52	15	22	51	29	28	29	45	15
Advanced			22	6			4			

(ETC/IW, 1998)

Table 7.8: Different types of municipal and industrial wastewater treatment for 1990, 1995 and later (in %), (treated municipal and industrial wastewater = 100%)

Country	Year	Mechanical	Biological	Advanced
AC10				
Bulgaria	1991	59	20	21
	1995	56	19	25
Czech Republic	1990	16	84	
	1993	16	84	
Estonia	1990	72	28	
	1995	54	24	22
Hungary	1990	62	31	7
	1995	58	34	8
Latvia	1993	22	77	1
	1995	9	45	46
Poland*	1990	52	40	8
	1995	40	49	11
	1997	39	44	17
Slovenia	1990	36	56	7
	1994	58	38	4
Other transition countries and CIS				
Croatia	1990	83	10	7
	1995	84	9	7
	1997	81	6	13
Ukraine	1995	9	89	2
	1996	8	91	1

Source: UN/ECE IEDS
*Poland: data from the Polish Statistical Yearbook, 1998, advanced treatment includes chemical and high efficient biological and chemical treatment with increased reduction of N and P.

Special country information

In Lithuania, in 1996, 17% of the total wastewater was not treated at all. About 43% of all wastewater was insufficiently treated, that means only mechanical treatment or ineffective biological treatment. Treatment, which met Lithuanian quality standards, was achieved for 40% of the total wastewater. These percentages do not include wastewater which meets quality standards without treatment, i.e. cooling water (EPR, 1998).

Latvia has 1570 wastewater treatment plants, of which 1/3 have only mechanical treatment, the remaining have biological treatment. About 20 % of the latter work with activated sludge systems. Nearly all mechanical treatment plants are hydraulically overloaded or in poor condition. About 40% of the secondary treatment plants fail to comply with national BOD standards and EU discharge requirements. The “800+” programme has now started in Latvia to improve the operations of wastewater treatment facilities in small and medium-sized towns (EPR, 1998).

In Bulgaria, the decline in industrial activity is reflected by an improvement of water quality in the main river basins of the country. There are 4450 large enterprises registered as discharging effluents, of which 2442 have some kind of treatment and 712 are listed as needing treatment systems. Out of 97 towns greater than 10 000 inhabitants, only 24 have sewage treatment plants and 29 are building treatment facilities (EPR, 1996).

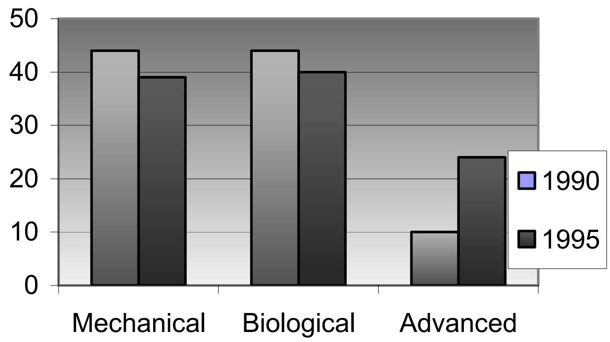


Figure 7.1: Annual average (in %) of different wastewater treatment types of seven Accession countries (see tab.C.2) in the period of 1990 and 1995.

Source: UN/ECE IEDS

Sludge in the AC10

According to the European Environmental Agency (EEA/ETC/IW1998) sludge production in the AC 10 in 1995 was taken as baseline to estimate the amount of sludge produced after implementation of the UWWTD. Estimates are based on sludge production of 60 g dry solids per person per day and the extent of sewage treatment.

In 1995, Poland was the country with the largest production of sludge (369’000’000 t dry solids), followed by Romania (163’000’000 t dry solids) and Czech Republic 120’000’000 t dry solids).

The following graphic shows how the estimated sludge production will increase from the baseline in 1995 with the implementation of the UWWTD, according to the scenarios mentioned in section 7.3.4.

As shown in Figure 7.2, there will be an increase of sludge production between scenario A and B because an increase in the population connected to sewers will produce more pollution load as shown in scenario B and C. There is no difference in sludge quantities between scenarios B and C because, although there will be a greater quantity of total sludge produced arising from the chemicals used to precipitate the nutrients, only the organic matter content of the sludge is being considered.

It is estimated that the sludge production of the EU 15 including Iceland, Liechtenstein and Norway will be 11.2 million tonnes dry solid in 2005. The AC 10 would increase this amount by about 10-15%.

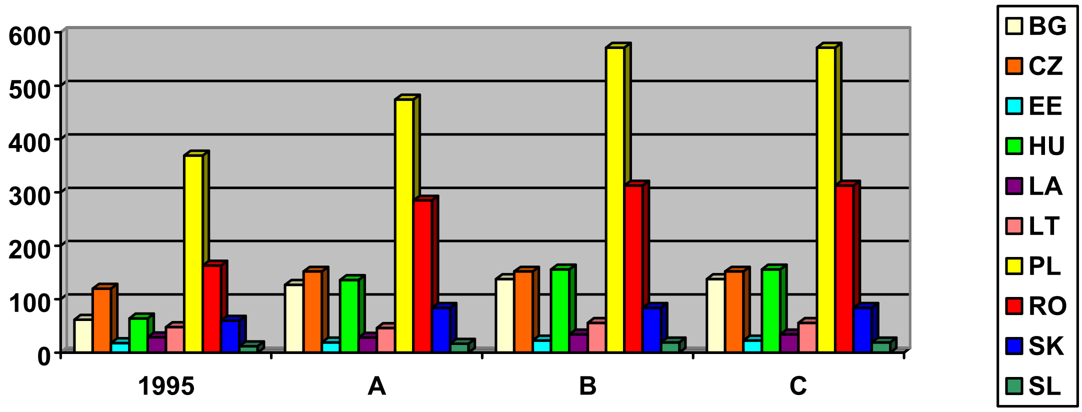


Figure 7.2: Estimated total sewage sludge production in the AC 10, in 1995 and after the implementation of the UWWTD, according to the 3 scenarios.
Source: EEA/ETC/IW, 1998

7.3.3 Wastewater treatment in the other transition countries and the CIS

For other transition countries it is difficult to come to any conclusion. In countries facing wars, like in the states of former Yugoslavia, or in Azerbaijan, Armenia and Georgia large improvements cannot be expected. Unfortunately, no data or information were available for these countries.

In the Russian Federation wastewater treatment experiences huge regional differences. In the cities, treatment facilities exist but their efficiency is dependent on the degree of maintenance and reconstruction. A good example is the wastewater management projects within the watersheds that provide drinking water for Moscow. With the support of USEPA, World Bank and international enterprises, in three regions around Moscow (Tver, Dimitrov, and Smolensk) modern industrial and municipal wastewater treatment and disposal facilities are establish to improve considerably the situation in this densely populated and polluted area (WHO, 1996). In rural areas wastewater treatment facilities are rare and mostly of low efficiency.

In most **CIS** countries the major problem is the poor quality and inefficiency of treatment plants due to the technical state and capacity of existing installations. Insufficiently trained personnel, lack of treatment chemicals and spare parts are other general problems. In most rural areas there are no treatment facilities at all. Often, in less developed rural parts, most of the people are not informed about the potential hazards of untreated sewage on human health and so not much effort is undertaken from the community level to improve the situation.

In Albania there are no wastewater treatment facilities at all to serve the collection systems in any municipality. Therefore, collected domestic and industrial sewage is discharged untreated into surface waters and the Mediterranean, regardless of beaches used for bathing (WSSCC, 1997).

According to the EPR, 1999, in Croatia in 1997, just over 20% of all wastewater was treated, with large regional disparities. Special emphasis is given along the Adriatic coast in order to improve bathing water quality. Sea outfall pipes have been built in four towns on the coast. It is considered, that for the time being mechanical treatment is sufficient, because of the inefficiency of biological treatment during two or three months in summer when the population increases up to 30-fold at the coastal region.

Within the Danube Convention, 22 pollution hotspots were listed in Croatia, mostly municipal wastewater discharges of large towns. In 1994, a new municipal treatment plant was built in Rijeka, and other projects are under construction in Split and Kastela Bay (first step: only mechanical treatment). The war destroyed several treatment plants, which are not yet rebuilt, because priority has been given to the reconstruction of the water supply system.

On Croatian islands there are only a few sewage systems. For the most part, wastewater is discharged into the sea after simple preliminary settling. Biological facilities are rare and the quality of their treatment is questionable.

In general, the bulk of Croatian wastewater (81% in 1997) is only mechanically treated, which means poor performance yields, except for suspended solids, and a poor effect on dissolved pollution. About 6% of wastewater is biologically treated and 13% is subjected to combined treatment. The reduction in pollution load is estimated at about 25% of the water treated. Sludge production by wastewater treatment plants is not recorded. Wastewater from industry (30% in 1996) is discharged through domestic sewer systems into municipal treatment plants, as industry is obliged to use and contribute to the plants where they exist. Another part of industrial wastewater is discharged directly or after preliminary treatment into surface waters.

Since wastewater treatment was made a priority a few years ago, many municipal installations have been or are being built, but their ability to operate is not always a given. Quit often, municipalities invested in installations, but now do not have the money to cover the loans and so operation and maintenance is hampered. The result is bypassing the often non-operational treatment facilities and discharging the effluents untreated. The water agency (Hrvaske Vode) is trying to finance, at least partly, new projects to equip more urban areas.

7.3.4 Three EEA baseline scenarios for the implementation of the UWWTD in the AC10

At present, about 40% of the population of the AC 10 is not connected to sewers. Thus, the effect of implementation of the UWWT-directive will depend significantly on the development of sewage treatment in the coming years. To make the possible effects more visible, the European Environmental Agency (EEA, 1999) proposed three future “what if” scenarios for the AC 10. All three scenarios are based on the following assumptions:

- the AC 10 population remains constant at 105 million persons,
- only the population connected to wastewater treatment and not industrial discharges to urban wastewater plants will be considered and
- the rural population (31 % of the total population) will not be connected to sewers.

Scenario A
Moderate development of sewage and wastewater treatment as a requirement for normal areas (secondary treatment).

All cities larger than 10’000 inhabitants (50% of the population) will be connected to sewers and all their wastewater will receive secondary (biological) treatment. In cities with 2’000 to 10’000 inhabitants (19% of the total population) half of the population will not be connected to sewers and half will receive secondary treatment. Except for the Czech and Slovak Republics where all wastewater will receive secondary treatment. In this scenario the population not connected to sewers will fall by 1 million compared to the present situation. About 41 million persons or 39 % of the total will not be connected to the sewers. The majority of wastewater will be treated by biological treatment according to the UWWT Directive. A small proportion of the wastewater will be treated by secondary treatment plus nutrient removal.

Scenario B
High effort on sewage development and wastewater treatment as a requirement for normal areas (secondary treatment).

All cities larger than 2’000 inhabitants (69% of the total population) will be connected to sewers and wastewater treatment. All wastewater in the cities with more than 2’000 inhabitants will receive secondary (biological) treatment. In this scenario more sewage will be developed compared to scenario A. The population connected to sewers will increase by 9 million compared to the present situation. About 33 million persons or 31% of the total wastewater will not be connected to sewers. The majority of wastewater will be treated by biological treatment according to the UWWT Directive. A small proportion of the wastewater will be treated by secondary treatment plus nutrient removal.

Scenario C
High effort on sewage development and wastewater treatment as a requirement for sensitive areas (secondary treatment plus nutrient removal).

This scenario assumes a high effort on sewage development and wastewater treatment, with the whole country designated as a sensitive area. All cities larger than 2’000 inhabitants (69% of the total population) will be connected to sewers and wastewater treatment plants. All wastewater in the cities with more than 10’000 inhabitants will receive tertiary treatment (biological plus nutrient removal). In cities with 2’000 to 10’000 inhabitants (19% of the population) the wastewater will receive secondary treatment. In this scenario the percentage of the population not connected to sewers and treatment is similar to scenario B. In total 19% of the wastewater will be treated by secondary treatment and half of the wastewater will be treated by tertiary treatment. Finally, all countries except Slovenia, will have more than 40% of the wastewater treated in treatment plants with nutrient removal.

The predicted changes are illustrated in figure 7.3. The proportion of the population not connected to wastewater treatment is expected to decrease from current 40% to about 31% under scenarios B and C. At present most wastewater discharges are untreated or mechanically treated. In future wastewater will be either biologically treated (scenario A and B), or biologically with nutrient removal (scenario C). Scenario C is similar to the expected situation in the present EU following the implementation of the UWWT Directive. Only the proportion of population not connected to sewers is still higher in the Accession Countries.

Under scenario A and B, the extent of biological treatment of wastewater is expected to increase from the current 31% to 59% and 67%, respectively by 2010.

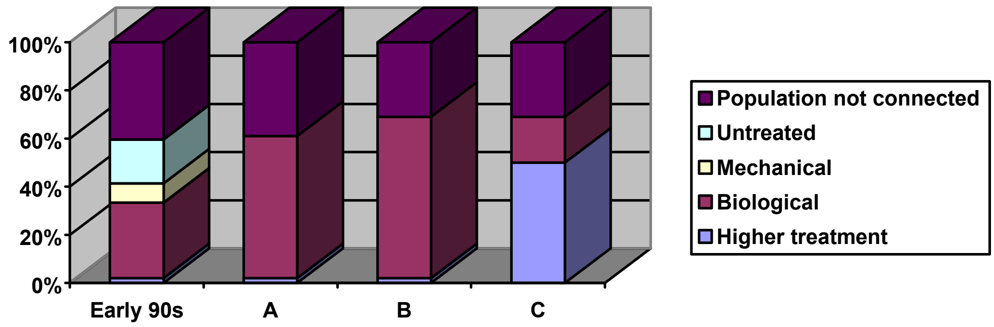


Figure 7.3: Development in wastewater treatment in the AC 10 according to EEA scenarios (EEA, 1999, ETC/IW, 1998)

The implementation of scenario A and B might result in a 60% reduction of discharged organic matter from currently 1.1 million tonnes to 0.45 million tonnes. Scenario C would give a reduction of about 65% compared to the current value. The discharged amount of nutrients for scenario A and B would decrease by 12% and 10% for phosphorus and nitrogen respectively. For scenario C a 50% reduction in phosphorus and 40% reduction in nitrogen discharges could be expected in 2010. This would potentially reduce the nitrate and phosphorus load from rivers in the AC 10 to both the Baltic and Black seas by around 15% and 28% respectively.

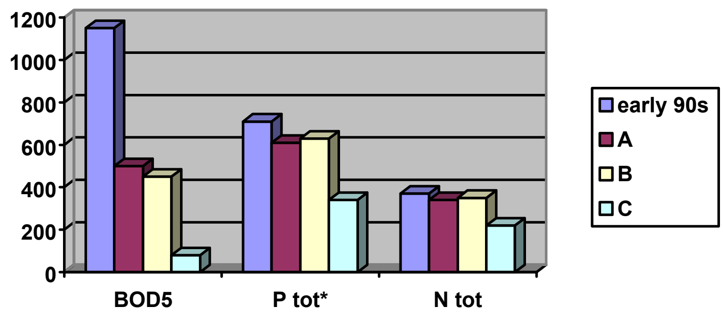


Figure 7.4: Change in emissions from urban wastewater plants in the AC 10 as result of the EEA scenarios (EEA, 1999, ETC/IW, 1998)

* Phosphorus discharges should be divided by the factor 10.

Note: (BOD_5 and N tot in ktonnes, P tot in ktonnes/10)

The costs for the most radical implementation of the UWWT Directive (scenario C) in the AC 10 are estimated at 9 billion EUR (about 100 EUR per capita) only for the construction of treatment plants. Extra cost will arise for additional sewer construction and sludge treatment and its disposal.

For the AC 10, data on municipal wastewater treatment was gathered from the European Environmental Agency (EEA, 1995b and 1998c) and data on municipal and industrial wastewater was provided by UN/ECE IEDS. Both sources were checked by the countries and subsequently used in this chapter.

7.4 Reuse (Topic d)

Reuse of wastewater and sewage sludge in agriculture should be strictly controlled in order to avoid chemical and/or microbiological contamination.

In the AC10, but most probably in all transition countries, the reuse of sewage sludge from treatment plants as fertilisers in agriculture is not common. A lack of knowledge of the real health risks and the wide adoption of unenforceable standards have tended to encourage the belief that reuse of effluents for irrigation is a costly process requiring sophisticated treatment technology. This has resulted in a failure to plan for wastewater reuse where sewage schemes have been installed. Especially in arid and semi-arid regions it is of high importance to include the reuse of treated wastewater as source for irrigation water. To achieve this and to ensure health protection, more realistic water quality guidelines are needed, taking account of the improved knowledge on epidemiological implications of wastewater reuse. A cheap, simple and effective solution is for example proper designed wastewater stabilization ponds used for secondary sewage treatment. The produced effluents are suitable for the use in irrigation and aquaculture. Wastewater–fed fisheries is used for example in Hungary (WHO 1989).

Only a few transition countries use wastewater for irrigation purposes, i.e. Poland and Hungary. In these countries the amount of municipal wastewater used for irrigation is very small; only 4% of the total wastewater generation in the case of Hungary. Indirect reuse, i.e. the abstraction of irrigation water from rivers receiving wastewater, occurs everywhere as a result of freshwater scarcity and the need to increase local food production. The surveillance of health criteria is in most cases not assured because of the lack of equipped laboratories and often the lack of well trained staff.

Reuse of sludge as fertiliser is traditionally accepted only from livestock breeding. Very little sludge from municipal treatment plants is used as fertiliser, not only because of health concerns (high heavy metal concentrations), but also simply because of no transport capacity to bring it to the fields.

The situation in Romania might serve as example of most of the transition countries. There is no direct use of wastewater (treated or untreated) for irrigation systems, sprinklers or to re-charge the ground layers. Neither the treated sludge is recommended (or collected) as fertiliser for health and ethical reasons. Despite good experiences in scientific pilot studies, the agricultural use of wastewater or sludge was not promoted. The official reasons were the high fertility rate of the Romanian soil and the lower costs and higher efficiency of chemicals used as fertilisers.

In the case of animal farms, the situation is different. Wet or dry methods to collect animal dejection is widely used to produce biological fertiliser according to a traditional method of "stable garbage", specific to these places- creating compost in natural conditions (Rojanschi, 1999).

7.5 Disposal (Topic e)

According to the EU Directive on Urban Waste Water Treatment (UWWTD) Member States (EU 15) have to ensure the disposal of sludge from urban wastewater treatment plants. Sludge disposal is subject to general rules or registration or authorisation in order to minimise the adverse effects on the environment. The disposal of sludge to surface waters had to be phased out by 31/12/1998 for EU 15. The implementation of the UWWT Directive in the AC 10 will considerably increase the quantity of contaminated sludge generated by the treatment processes. The sludge will require further action, which might have negative impact on the environment.

Sludge treatment and disposal accounts for about half the total costs of sewage treatment. The resulting benefits are an improved surface water quality, a decline in costs for drinking water treatment and general public health benefits, as well as use as fertiliser for agriculture.

Especially in the CIS, the disposal of untreated sludge is carried out on huge sludge fields. Sludge management is hampered by a lack of dehydration technologies. On sludge fields, the sludge is drying out naturally, which creates problems in the dry period of the year through dust and smell trouble for the surrounding population, as well as in the wet period of the year through washing out the sludge into water bodies and /or groundwater. Most sludge field capacities are exhausted, they are overloaded, and there is not much space to build new ones, except in Russia. Sludge fields are not always monitored, ground water and soil contamination are common.

Incineration of sludge is rarely used, because of the costs of proper instalment of air pollution abatement technology. The dumping of wastewater sludge into the Black and Baltic seas is decreasing because of the commitments related mainly to the HELCOM and Black Sea Conventions as well as to other marine protecting conventions or agreements, signed by the adjacent countries.

According to Rojanschi, 1999, in Romania nearly all sewage sludge is disposed on drying platforms. A small amount of sludge is also discharged into the Black Sea, mostly out of the bathing season. The equipment of the drying beds is quite often old, and maintenance is often not adequate. That leads to infiltration into the ground, contaminating the groundwater and soil. Filled drying beds were abandoned, without any further care, and new ones were created. Under the new political and social circumstances, in which a restitution of the land to the former owners has taken place or is going to take place, disposing sludge on drying beds must be radically reviewed. That solution was valid and justified under the circumstances of the state ownership on land, where the cost of the land were not significant. Today, more economic solutions have to be found like de-hydration, composting, or incineration. Currently, the implementation of these methods is intensively studied and proposed as solutions to upgrade some of the wastewater treatment plants in Romania.

In the future the picture has to change, because of new environmental laws against water and soil pollution, as well new ownership arrangements for land and treatment plants. It is becoming too expensive to use large areas for often uncontrolled and leaking drying beds and landfills which stay contaminated.
Municipalities have to find economic solutions suitable for public and environmental health, which might include the use of treated sludge for agricultural purposes. Incineration facilities for sludge are still limited in nearly all transition countries.

Treated or untreated wastewater is usually disposed to watercourses eventually finding its way to rivers and lakes. Examples of the rate of wastewater disposal are given below.

Pollution load of Lithuania

According to the EPR, 1998, wastewater discharges from urban settlements particularly along rivers represent a significant pollution source. Discharges from the seven largest cities, or 44% of the population, produce about 67% of all wastewater discharges. In terms of BOD_7

this is 74%, nitrogen discharges are 64% of the national total and phosphorus discharges are 60%. Pollution caused by industry has decreased over the recent years as result of reduced economic activity in certain key sectors.

The wastewater discharge which meets national quality standards without treatment, is mainly cooling water from the energy sector. Cooling water discharge increased by about 69% in the period 1992-1996. In 1996 it delivered up to 95% of the total wastewater discharge and was directly released into surface water. The remaining 5% wastewater requires treatment. This amount of wastewater decreased by about 31% in the period 1992-1996. Out of the wastewater requiring treatment, 40% is actually treated to meet national quality standards, 43% is insufficiently treated (not meeting standards) and 17% remains untreated. In 1997, out of the 787 wastewater treatment plants, 6% were only mechanical treatment plants and 85% biological treatment plants. Seven towns (Vilnius, Marijampole, Lazdijai, Silale, Raseiniai, Pakruojis, Moletai) remove both, phosphorus and nitrogen in their treatment plants, with a total capacity of more than 6 million m^3 per year. The general removal efficiency of biological treatment plants in terms of BOD vary between 93 and 97%, for nitrogen between 62 and 80% and between 37 and 80% of phosphorus. The table 7.9 shows the decreasing trend of the main pollutants discharged into Lithuanian surface water in the period 1992-1996.

Table 7.9: Trends in pollutants discharged into Lithuanian surface water in the period 1992 – 1996 (1992=100%)

Pollutant	1995	1996
BOD_5	66	52
Suspended solids	70	49
Oil products	65	47
Phosphorus	82	67
Nitrogen	72	61
Heavy metals	47	28

Source: EPR, 1998

Public health impacts

Microbial contamination of drinking water and food is often related to insufficient or untreated wastewater, inadequate sanitation and hygiene or to the natural occurrence of microorganisms in water. That might be associated with a relatively high incidence of outbreaks and isolated cases of dysentery, hepatitis A, typhoid, Salmonella and other enteric infections.

For example, Lithuania and Latvia are countries with an incidence of viral Hepatitis, which is about 10 times higher than the EU average, but still less than in other CIS countries (EPRs, 1998). The most affected countries are Ukraine and the Central Asian States of the CIS. Outbreaks of Cholera are reported in Ukraine (1994-95), in Moldova (1995) and in Romania (1991-93) and in Albania (1994), (WHO/EURO, 1999).
Ameobic dysentery is another disease which can contaminate surface water through sewage effluents. The number of cases reported from countries that maintain records is generally low. Outbreaks were reported, according to the EEA/WHO questionnaire, from Slovenia in 1991, from Hungary and Lithuania (WHO/EURO, 1999). Shigella species, causing bacillary dysentery, can occur if drinking water is contaminated with sewage. Large outbreaks of this disease were recorded in Romania in 1995, and in the 3 Baltic states with an especially severe outbreaks in Lithuania in 1996 (about 70 000 people), furthermore in Moldova and Albania, all in 1996.

Giardiasis outbreaks have been reported in Slovenia, of which 40% of these cases were linked to drinking water contamination. There were also outbreaks reported from Estonia, Lithuania , Hungary and Slovakia in 1996.

According to the available data from the EEA/WHO questionnaire of 1997, the occurrence and incidence of some water related diseases like bacillary dysentery, giardiasis, hepatitis A and typhoid, where insufficiently treated sewage might be a major contamination source, was more frequently found in the European transition countries than in Western Europe (WHO/EURO, 1999). In Central and Eastern Europe, a general decline in acute intestinal diseases is reported. Some reasons might be the drop in economy, because of a decrease in collective food distribution, (individually grown food has less chances to become contaminated) and lower density in schools and kindergartens, because of fewer children being born.

Political instability, like that found in parts of the Balkan or in the Caucasian region, leads to mass movements of refugees, not having access to adequate water supply and sanitation, which can have severe impact on human health. Sanitation in refugee camps is limited, will be discharged directly into nature and is normally not covered by statistics.

7.6 Policy and institutional framework (Topic f)

The Urban Waste Water Treatment Directive (UWWTD) of the European Union is the most important guideline on the wastewater sector for the whole of Europe in the next decade and beyond.

The UWWTD defines standards for the collection, treatment and discharges of urban wastewater and wastewater from some industrial sectors. All urban wastewater discharges greater than 10’000 p.e. to coastal waters and greater than 2’000 p.e. to fresh water and estuaries will be subject to secondary treatment by the year 2005. Furthermore, discharges from a list of industrial sectors with direct discharge (greater than 4’000 p.e.) shall also respect the above regulation.
Member States have to classify their national water bodies as sensitive, normal or less sensitive according to eutrophication effects. In sensitive areas, discharges are subject to more stringent treatment with supplementary phosphorus and /or nitrogen removal, whereas in less sensitive areas less stringent treatment than the general secondary treatment prescribed is accepted. Primary treatment is the minimum requirement in less sensitive areas.

All municipalities smaller than the lower threshold of 2’000 and 10’000 p.e. should also be subject to appropriate treatment by the year 2005. However, no specific criteria are given in the Directive. Full implementation of this directive for the 15 Member States is expected before 2010, meaning, that 95% of the total wastewater is discharged to sewers and only 29 million persons would not be connected to sewers. Most wastewater would either receive secondary treatment or secondary treatment plus nutrient removal.

Similar baseline scenarios have also been developed for the implementation of the UWWDT in AC 10. The effect of implementation will here significantly depend on the amount of sewage produced in the coming years.

Before the break-down of the political system, all transition countries had a state-controlled economy with a complex system of subsidies, taxes and monetary restrictions. Economic interests had priority over environmental protection. While ambient environmental quality standards existed (mostly too strict), there were no practical means of controlling operations to ensure their enforcement. Plants had a general obligation to meet emission limits, though no deadlines were set for compliance, or special agreements were set between the enterprises and the control agencies in order to ensure further production. The absence of a permit system meant that no plant-specific requirements were really in force. The enforcement systems relied on fines and civil penalties, which proved largely ineffective. Often, the production process, the discontinuity in delivering of material and spare parts and the use of (often out-dated) technology did not allow environmental quality standards to be met. So the large state-ruled plants planned in advance certain amounts of money to pay the state penalties. For the population drinking water supply and wastewater treatment were free of charge, so there was no interest in wise use or reuse of water. Insufficient supply including frequent water and energy cuts led to a waste of water. This is the reason why at present many transition countries have extreme difficulties in introducing taxes on water supply and wastewater treatment.

Water quality monitoring was carried out by all transition countries having a quite dense network. Laboratory analysis was mostly limited to conventional parameters (including heavy metals and pesticides). For analysing more sophisticated chemical parameters or newly developed chemicals the laboratory equipment was mostly not available.

Nowadays, in order to implement the Urban Waste Water Treatment Directive of the EU, all AC 10 will ultimately have to align their water policy and legislation with that of the European Union. Most of the AC 10 are now working towards this goal, despite the fact that it will take most probably longer than one decade to reach full implementation. All transition countries have already changed or are going to review and improve their environmental legislation. However, the new legislation is at present at very different stages in each individual country and not always in line with the requirements of the UWWTD (ETC/IW, 1998).

In recent years, all Accession Countries (AC 10) introduced new laws and/or regulations on water, which are approaching the requirements of the UWWTD. Nevertheless, additional regulations, mostly on effluent quality discharged from urban WWTP, must be developed and implemented for nearly all AC as soon as possible. In several AC and in the other transition countries the responsibility for wastewater collection, treatment, disposal etc. is divided into several ministries, what makes concerted actions more difficult (i.e. Bulgaria). Quite often the structure and the content of new laws or regulations overlap or contradict other national laws. A weak co-ordination within and between national ministries and departments does not contribute to a strong enforcement of environmental laws and is one reason for ineffective penalties and taxation for pollution control in most transition countries.

Sensitive areas, as required in the Directive, have been identified by Czech Republic and Estonia (state-of-art in 1998). Several AC still lack water quality standards and classification schemes for receiving waters that are in compliance with the Directive (i.e. Estonia and Hungary). There is much more work to do in regard of Water Use Permit Regulations, and their enforcement, which is quite advanced in Czech Republic and Poland for example. In the Slovak Republic, the basic legal standards for conservation and use of water, covering also wastewater treatment plants, are still based on separate Slovak Technical Norms.

7.6.1 Estonia

The example of Estonia, one of the Accession countries, might give a short overview of the most common problems and show how this country handles them (EPR, 1996 and ETC/IW, 1998).

Legislation
The Water Act of 1994 and its amendments in 1996 and 1997 provide the basic framework for the countries water legislation.

Wastewater discharge requirements were introduced by the Regulation concerning requirements on wastewater discharge to water bodies and ground of 1994 and amended by the Regulation on restriction of requirements on wastewater discharge to water bodies and ground in 1994. So all ground and surface water abstraction and discharge requires a permit delivered by the Regional Environmental Department. The permit determines the volume of water that can be used and also the amount of pollutants that can be discharged under consideration of the requirements of the Convention on the Protection of the Marine Environment of the Baltic Sea Area. Furthermore, the rate of fees for abstraction and pollution, the user has to pay are determined. Any discharges over the permissible limits the polluter has to pay five times more. Old industrial enterprises with higher pollution volumes are temporarily tolerated; new or reconstructed ones and new wastewater treatment facilities have to follow stricter rules in accordance with EU and HELCOM standards.

The requirements on wastewater discharge were complemented in 1995 by a regulation establishing pollution damage compensation rates, which set up the related economic instruments and taxation system. In 1998, a Regulation of the Government on the enforcement of requirements concerning the quality of water discharged from urban wastewater treatment plants into water bodies or introduced into soil came into force. In the same time another Regulation of the Government on the rates for pollution charges for the discharge of pollutants into water bodies, groundwater and soil was introduced.

The requirements for treated urban wastewater discharged into water bodies or introduced into soil specify requirements for collection, treatment and discharge of wastewater into water bodies and soil to protect the environment from adverse effects. Requirements for the discharged water depend on the pollution load as well as the sensitivity of the recipient.

Treatment plants which become operational later than the 1 January 1999, have to ensure the appliance of discharges to the maximum allowable concentration depending on the sensitivity of the receiving water body (6 sensitive area categories exist). There are also categories for unprotected and poorly protected groundwater areas, 2 categories for less sensitive recipients and 2 categories for moderately and well-protected groundwater (ETC/IW, 1998).

Water quality standards
At the moment, there are no national surface water quality standards or classifications to estimate the state of rivers and lakes, but they are under preparation in accordance with EU requirements.

At present, the Regional Environmental Departments are not able to efficiently implement and enforce the permit systems. They lack staff and expertise. In addition, the Environmental and Nature Protection Inspectorate, which is in charge of monitoring and controlling compliance with the permitting system at the central level, lacks the capacity and necessary co-ordination with the regional offices and the permit holders.

Monitoring
Ground and surface water bodies are regularly monitored and assessed. Nevertheless, because of inadequate monitoring, the database on water quality is not yet completed or fully reliable. A comprehensive monitoring and information system is under development.

Pollution load
For the pollution load (expressed in population equivalents (p.e.)) used is the organic biodegradable load (BOD7) of 60g of oxygen per day. The requirements for BOD7, COD, TSS, P tot, N tot, monophenols, diphenols, and oil products differ according to the sensitivity of the receiving area and the implementation time.

Institutional arrangements
The Ministry of Environment is responsible for developing water legislation, setting water standards, developing water resource and water use management guidelines and strategies. Furthermore it is responsible for the technical control of water supply and sewage systems and the development of regulatory measurements, drafting and control on implementation of legislation, state level co-operation projects, research, training, monitoring along with issuing and checking compliance with water permits. The Regional Environmental Departments at the county level are in charge of implementation of the water resource management policy in close co-operation with municipalities. Its duties are also the implementation of water protection and use policy; planning and protection of water resources and implementation of State control; running data systems (monitoring) of water quality and wastewater discharge on county and municipal levels; and issuing discharge permits.

Municipalities are in charge of water supply and sewage collection (implementation of State policy at local level, water use permits, treatment). The Health Service under the Ministry of Social Affairs is responsible for checking the drinking water quality.

Policy framework
The current policy for water management is a balanced system based on command and control (emission standards, permits for water use and discharges, State inspections) and on economic instruments (water use and pollution charges, threshold levels, differential charge rates, fines/subsidies, grants and soft loans).

The established water permits of the Regulation of 1994, one for abstraction and one for pollution, are set somewhat arbitrarily by environmental experts, without reference either to the economic situation or to public debate. The rates of these charges are still too low to have visible incentive effect on the consumers and polluters. These rates have to be substantially higher to fully cover investment, maintenance and operating costs. However, the payments help to fund the investments in municipal sewage and industrial wastewater treatment plants (in 1996, 50% of the pollution charge goes to the national Environmental Fund and the other half to the Regional Environmental Departments in the counties).

Estonia's main priority today is urban sewerage and industrial wastewater treatment. Most of the 13 Estonian "hot spots" identified by HELCOM entail water investments (mostly combined industrial and municipal wastewater treatment), which are too large to be entirely financed by national funding in the short term. Several important programmes are already, or will be, implemented with the support of multilateral, subregional and bilateral institutions (much of the programmes involve upgrading (from mechanical to biological or higher) wastewater treatment plants) (EPR, 1996).

7.7 Training (Topic g)

Capacity building in the water (including wastewater) sector, both at national and local levels, is needed in all transition countries. The ministries or State agencies, dealing with water and wastewater and/or education do not always have the capacity to support or create efficient training programs at the technical and professional level. Such training very often comes as part of technical assistance and investment activities of west European countries, North America (in the form of bilateral co-operation), the European Commission (PHARE and TACIS programmes), different international environmental foundations and funding agencies, banks, as well as United Nations, and US EPA. Another type of co-operative training is established through bilateral arrangements between enterprises, institutions and municipalities of the transition and Western countries.

During the last few years, most training and education programs at university level have been reviewed and updated approaching western standards in environmental sciences and engineering. Now they also cover management issues, legal aspects, monitoring, assessment and sustainable development. Opportunities for post-graduates to attend courses at home and at foreign universities were created. Many firms co-operate with universities and research institutes. The latter are responsible for theory, whereas national or foreign consultancy firms give practical training.

The access to new international research differs between transition countries. Most of the Accession countries have quite good access to international literature, they take part in international conferences and have relations to leading research institutions outside the country or even conducting common projects with them. The other transition countries, but particular the CIS, face here much more difficulties. With the exception of Russia, all the other State universities and colleges of former Soviet Republics have mostly only sporadic access to international specialised literature, only little contact with acknowledged international research centres and no financial resources to invite scientists for lectures or send students somewhere else. The available computer equipment is very limited and often quite old. Furthermore, many of younger graduated academics try to get hired by an international company or to work in Western Europe or in North America to have better professional chances and to earn a much better salary. The overwhelming part of these young researchers settle down in the "West" and are "lost" from their own country. In the last few years private universities and specialised colleges have appeared, but not in the environmental/water sector.

On the operational level, specialised training for wastewater treatment plant workers does not always exist. Normally they follow the normal apprenticeship of an electrician, plumber or locksmith etc. and get on-the -job training supervised by engineers. In the CIS, this kind of education concerning "Vodocanal" is provided by the State, the owner and ruler of the water supply and wastewater network and treatment plants on a country and regional level. Often the job efficiency is limited because of insufficient education, lack of material and chemicals, or break down of equipment. Another reason of inefficiency is the habit of former times to give as many people as possible a work place and therefore an income. The state ownership of wastewater plants continues still with this habit. In areas where the wastewater plants and related services are privatised the situation has changed and the market economy took over. Specific training in plant operation, process control and instrument operation would improve the treatment performance even with limited resources.

A good example of an Assession country is Estonia. Here, in 1993, a special post was created in the Ministry for Environment to co-ordinate and direct environmental education and training for specialists and promote contacts with other ministries, universities, schools and the media nationwide. The training courses cover a wide range of topics including development of legislation and standards, Environmental Impact Assessment (EIA), project preparation and management, compliance and enforcement, reduction of agricultural pollution, wastewater treatment, water protection etc. Special programmes cover training for chemical laboratory workers, for staff members of the Ministry for Environment, the Regional Environmental Departments and other ministries and industry. Most of all these courses were financed and provided by Western Europe. But also national companies, like the Estonian Water Company, offer training programmes on water management issues, including wastewater networks and treatment technologies (EPR., 1996).

The following selection of universities and institutions is not complete, but indicates some possibilities for professional training on wastewater management in Central and Eastern Europe.

Central European University, Budapest, Hungary
Department of Sciences and Policy;
training in: Wastewater treatment in rural areas, environmental standards and water quality.
http://www.personal.ceu.hu/departs/envsci

Technical University Wroclaw, Poland
Faculty of Environmental Engineering
Training in: water supply/wastewater treatment and solid waste disposal
http://www.sun1000.ci.pwr.wroc.pl

Czech Technical University, Prague, Czech Republic
Department Environmental engineering
Training in: water engineering and water management
http://www.fsv.cvut.cz/ascii/educat

Technical University Budapest, Hungary
Department of Water and Wastewater engineering
Training in: water engineering and water management
http://www.bme.hu/en/

Moscow Institute of Physics and Technology, Moscow, Russia
Department of Biophysics and Biochemistry, Ecology
Training in: technologies for waste and sewage treatments
http://www.mipt.ru/index_en.htlm

7.8 Public education (Topic h)

Public awareness of environmental issues is relatively high in all transition countries, but reflects more the immediate surroundings than the whole country or region. Public environmental education is still a process which has only started recently and which needs a lot of attention from governments and other sites. Hereby, environmental NGO's play a prominent role.

The creation of environmental NGO's, composed of environmental professionals and other interested people, especially young people, was an important starting point for wider public awareness of the environment. According to the new environmental laws, all people have the right to get access to environmental information. Public participation in environmental decision-making is also part of the new legislation. At present, most of the transition countries signed the UN/ECE Convention on Access to Information and Public Participation in Decision-making and Access to Justice in Environmental Matters.

Governments are obliged by law to publish information about the state of the environment on a regular basis. Beyond this, it is more or less up to the single ministry which other kind of environmental information they release to the public, including to NGO's. Public access to environmental-relevant data from other departments and ministries is in most cases very limited. In most transition countries, information about planned projects and their local environmental effects as well as participation in Environmental Impact Assessments is still not easy to obtain for NGO's and the interested public.

In most transition countries, there is no co-ordination between the Ministries of Environment and the Ministries of Education to guarantee a comprehensive and systematic school toward professional environmental education. At the level of kindergartens and schools, there are many different projects ongoing to involve the youth in environmental actions and create awareness and sensitivity. But how much environmental issues are regular part of school curriculum's is difficult to say and not often a reality. For adults, environmental education is often provided by environmental NGO's with workshops for professionals, or project-related discussions or protests for the public. Furthermore, mass media information about environmental issues and new development projects, but also media campaigns, including TV-spots or documentary films, about accidents or other special events inform and educate the population. Besides, companies with environmental development projects (mostly financed from outside the countries), are obliged to hold public workshops introducing the projects to the local population and discuss them with the people.

In Ukraine, many environmental activities on local levels, in pre-schools and in schools, are initiated or supported by NGO's. There are about 100 environmental NGO's, the majority are acting locally. Due to the Chernobyl catastrophe, public environmental awareness is still comparatively high in Ukraine, although public interest in environmental protection issues is shrinking in view of the severe economic situation. The press regularly covers environmental issues. The highest priority of environmental issues has air and drinking water pollution, followed by nuclear safety and waste. The Ministry of Environmental Protection and Nuclear Safety is obliged to submit every year to the Parliament a "National Report on the State of the Environment" and to provide ecological information to the interested public and private institutions. This report and the monthly bulletin "Living Ukraine" have summaries in English (EPR; 1999).

In Lithuania, environmental yearbooks, quarterly "State of the Environment Reports", environmental monitoring and annual environmental media reports were published by the Government. To a large extent this information is available in English and provided on the Internet. Public participation is sufficiently covered by the new environmental laws and regulations. However, access to information appears to be a crucial requirement for NGO's. Active public participation in environmental policies has to be encouraged, NGO's have to be supported and the dissemination of environmental information via mass media has to be improved. Environmental training should be extended to experts in all ministries concerned, as well as in all regional and local administrations involved in environmental management EPR, 1998).

In Estonia, public awareness and concern for the protection of the environment plays a substantial role in the political process. Environmental issues have been a contributory stimulus to arouse the national consciousness in the process of restoring the countries independence. Several NGO's have been established and public pressure has stopped i.e. the production of phosphorite. However, the environmental movement has waned over the last years because public attention is more directed to the severe economic situation in the country. New legislation obliges the Government to provide environmental information to the public. However, the procedures which information will be published and how to obtain relevant information as well as how to participate in decision-making process are remaining still unclear. Procedures for access to environmental information (from Government, but also industry and agriculture) need to be clearly defined.

Latvia's recent history has demonstrated a strong connection between environmental criticism and the fundamental political changes. Public awareness of environmental issues in general is high. NGO's can not always be clearly distinguished from government. Environmental education has no formal status, it is treated as a cross-curricular theme. There is no formal recognition of the importance of environmental education from the Government. Furthermore, there is a lack of co-ordination between the ministry of Education and Science and the Ministry of Environmental Protection and Regional Development. This results in overlapping activities and parallel events. In school projects or special camps pupils became familiar with environmental issues. National school programmes, often involving 10 – 30 schools across the country, are a great success. Examples are the National Olympiad of Environmental Projects organised by the Curriculum Development and Assessment Centre. "Environmental education in Latvia" is a three year project of the Norwegian and Latvian Ministries of Education, involving 16 schools. Each school has chosen a different environmental topic which will be published and later used by teachers as educational material. In co-operation with the UK, the children environmental school of Latvia developed a project on " Implementation of Environmental Education Strategy in Latvians Schools". Other national projects (on energy, the Daugava river, etc.) were carried out with the involvement of dozens of schools all over the country.
The main difficulties are valid for most of the transition countries:

- The teachers are underpaid, often not well trained and there is a lack of educational material.
- Schools don't have much experience with cross-curricular work and active approaches to teaching.

In Slovenia the responsibility of environmental education is distributed to different ministries and institutions. Education in kindergartens, elementary and secondary schools are under the responsibility of the Ministry of Education and Sport. Graduate and postgraduate education are in the hands of the independent universities. After establishing a new law on Education in 1996, the National Curriculum Council and commissions were created including the Cross-Curriculum Commission on Environmental education. Nevertheless, an integrated environmental education does not yet exist.
The country has joined the European programme "Eco-Schools", which aims to involve pupils in elementary schools, their teachers and parents in predetermined environmental activities every year. Other initiatives like environmental training courses for schoolteachers were initiated with the support of NGO's and the national Board of Education and with relevant PHARE programs.

In Croatia, again NGO's did the first step to foster national environmental education. The NGO "Nature Friends Movement" has been conducting national environmental education programmes for several years. It has been nominated as national co-ordinator and operator for the European Blue Flag Campaign and the Eco-Schools Project in Croatia, which started in 1997. The Croatian authorities have joined this project in order to improve environmental education in schools as part of the official school curricula. At present, both projects are jointly carried out with the Ministry of Education and Sport and the Ministry of Tourism. The Blue Flag project involves monitoring the water quality on beaches and marinas, and the Eco-School project is targeting different environmental matters for both the elementary and secondary school students throughout the country. The Croatian State Directorate for the Protection of Nature and Environment (SDEP) takes part in the implementation of the Eco-Quiz show “Our beautiful homeland” and “Days of Bread-Days of Gratitude for the Fruit of the Earth”, involving again elementary and secondary schools in the whole country.

The general public interest on environmental matters is mostly concentrated on the damages which happened during the war and local projects influencing daily life. More information about Environmental Impact Assessment procedures would enable NGO’s and the public to be interested and included in decision-making. Information about planned developments should be published at an early planning stage to facilitate public participation and to improve public acceptance of individual environmental protection projects.

In Romania, both the Government and NGO’s are responsible for raising public environmental awareness and education. The Government is carries out workshops, conferences and is publishing brochures, photo exhibitions etc, to promote public awareness and education. Several environmental NGO’s, especially young people (the Ecologist Youth of Romania, Terra Nostra etc.) organise periodically action of waste collection from river beds, monitoring water courses in order to find out illegal contamination sources etc. Another form of environmental education is realised through Water Inspections or Environmental Inspections at local levels, which apply fines for people washing cars in the vicinity of rivers or lakes or throwing garbage into a water course.

A broader public understanding of the benefits of an improved and technologically advanced wastewater treatment for public health, and a healthy urban and rural environment is recognised as a prerequisite for any development in this sector. This is reflected in school education at all levels. Kindergartens as well as elementary and secondary schools have introduced environmental education, and they carry out excursions to drinking water and wastewater treatment plants.

Another form of public education is given through water companies, involved in or financed by international programs. Part of their work is to inform the local people and to carry out public workshops to inform/educate about and discuss projects with the local population. With the support of local mass media this form of education activities reaches large sections of the population and helps to create environmental awareness (Rojanschi, 1999).

7.9 Financing (Topic i)

In most transition countries, the highest percentage of the environmental expenditures for capital investments and current expenditures as a share of the total expenditures is dedicated to water protection (e.g. in Latvia, Lithuania, Estonia, Moldova, Ukraine, etc.).

The main sources of financing environmental expenditures (including wastewater facilities) in transition countries are the following:

- the State and municipal budgets,
- funds of enterprises,

- extra budgetary funds,
- foreign loans and grants.

For the financing of the construction or reconstruction of wastewater facilities in most cases the municipal or State budgets alone are insufficient. Therefore, a combination of different sources takes place, often with loans or credits from national and/or international banks and/or with money from extra budgetary funds. In some countries, like Ukraine, environmental expenditures are primarily financed by enterprises. These enterprise funds include also foreign loans and credits, as well as municipal or State allocations.

Most transition countries created a special environmental fund as an instrument to improve funding and the efficiency of environmental payment and expenditures. The environmental funds include, at least to a certain percentage, water pollution and water use charges of the industry and households, fines for wastewater generation, and all the other charges, fines and penalties for environmental pollution (air, waste, etc.). However, in many transition countries this important finance source cannot be used efficiently, because the enforcement of legally existing financing schemes for environmental protection is hampered by the current economic situation. At present, it is not possible to enforce environmental payment in their full legally foreseen form in order to avoid bankruptcy of enterprises. In several transition countries the polluter-pays principle is not introduced in practice as a powerful economic tool, again because of the unstable financial situation of most enterprises. Furthermore, enterprises should be convinced and supported to synergise environmentally friendly and economically sound solutions in order to invest in productivity and improving environmental performance. However, to encourage businesses to take low-cost measures to minimise emissions during the production process, an incentive is needed rather than punishment.

In **Croatia**, the water management sector has developed a comprehensive system of charges, grants and other economic instruments, like sanctions, penalties and fines. Water protection charges (effluent charges) are only 25% of the average purification price (in contrast to the Law on Water Management financing, which stipulates full cost coverage). This is because of the severe economic difficulties of the country and the substantial war damage. Effluents are subject to permits. Charges have to be paid to Hrvatske Vode, the State water management agency. In 1997, about 85% of the invoiced charges to households were actually paid (only 74% in 1994). Other relevant charges are water use charges (abstraction), which vary between the regions, between water user, type of water use and source of supply. For households these charges are between US$ 0.07-0.10 per m^3. Charges for industrial users are 10-30% higher. The charges go to the local government for financing investments for land improvement of all kinds. Furthermore, payments of fines related e.g. to the generation of wastewater and sewage go to the county budget. Payment is usually determined by a court, on submission of the case by environmental inspectors. However, the fines foreseen are too high and in general the court ruling is ignored in order to prevent the closing down of the enterprises.

The Croatian legal system has three major public financing instruments for environmental protection; the state and local budgets, special accounts, and extra budgetary funds.
In practice only two of them are used. They are the state and local budgets, which are the main sources for water management, and the special account of the Croatian Water Management Agency Hrvatske Vode. In addition, funds from environmental charges and fees are also used for environmental expenditures in the water sector. The role of local governments and self-government units is significant, they organise various public services, including wastewater management. Public utilities are managed either by private companies on the basis of concessions, or by public enterprises, which are owned and managed by local governments. Both get financed, among others, by fees charged for public utility services or

compensations. Unfortunately, in many cases, municipalities which invested in wastewater do not have enough money to cover the loans to operate and maintain the equipment. So they bypass their empty facilities and discharge untreated. At the same time, new projects are being designed and partly financed by Hrvatske Vode.

Hrvatske Vode has a special account for water management. The revenue was about 190.7 million US$ for 1998, of which 25% came from the State budget, 21% from water use charges, 19% from water basin charges, 19% from water protection charges, and the rest are other. Expenditures for 1998 were about 216.8 million US$, of which 55% went for water projects and investments, 29% for maintenance for existing water infrastructure and 16% for others including salaries. The financial deficits, which can not be covered by these two sources, are mostly covered by credits and loans from national, foreign and/or international banks. Croatia participates in the Regional Environmental Programme for the Danube River Basin and the Danube Action Plan and benefits furthermore from loans of the World Bank and the European Bank for Reconstruction and Development. These loans are also used for investments in industrial wastewater facilities. The volume of loans is expected to grow significantly in the coming years (EPR, 1999).

In **Ukraine**, there are the following sources for financing environmental expenditures; the State and municipal budgetary funds, funds of enterprises, and foreign loans and grants.
The state budget finances programmes that target state objectives and include also revenues from polluting the environment.

In 1992, Ukraine established extra budgetary funds which include parts of pollution charges, fines and penalties. These funds were created at national, regional and municipal levels, but they play a minimal role in the total expenditures. The overwhelming part comes from enterprises (Table 7.10).

Table 7.10: Environmental expenditure by environmental sector in Ukraine, 1992-1997 (in million US$, current prices)

	1992	**1993**	**1994**	**1996**	**1997**
Total expenditure	**464.56**	**524.43**	**569.04**	**1316.87**	**950.06**
Capital investment as share of total expenditure (%)	7.5	13.6	11.1	9.6	8.2
Water protection (%)	55.8	57.9	61.3	49.1	53.1
Current expenditure	**429.8**	**453.13**	**505.98**	**1`190.07**	**871.68**
Current expenditure as share of total expenditure (%)	92.5	86.4	88.9	90.4	91.8
Water protection (%)	57.4	65.6	71.9	53.6	63.8

Source: EPR Ukraine, 1999.

Since 1993 the investment share dropped from 13.6 to 8.2% in 1997 of the total environment expenditure and further drops are expected. Environmental investments as well as current expenditure are primarily financed by the companies own funds. These companies funds include foreign loans as well as municipal and State budget allocations. It is therefor not very clear from where the money comes and how effective the economic instruments like pollution charges etc are. The contribution of foreign funds to environmental expenditure is also difficult to assess.

Integrating environmentally related economic instruments into economic development policies is very difficult in Ukraine. The macroeconomic situation is characterised by high inflation, budgetary deficits, foreign debt servicing problems, the development of barter trade, and overall policy uncertainty. A further complication is the fact that many institutions give a relatively low priority to environmental protection. Weak institutional capacity building for environmental protection at all levels up to the ministries is another reason. Funds available for environmental policies are extremely scarce. The State or regional budgets are not always able to finance even legally prescribed expenditures, and the competent environmental authorities are not in the position to enforce payment of environmental charges, fines and penalties. Therefore, more attention and analysing efforts have to be devoted to studying the efficiency of economic instruments (EPR, 1999).

In **Lithuania,** the main sources of finance for environmental expenditure are State budgetary and extra-budgetary funds, funds of enterprises and foreign sources.

Environmental investments from the State budget are channelled through municipal budgets. The State's national and sectorial investment priorities, including the environment, are spelled out in the Public Investment Programme PIP. PIP includes investment programs, which are mostly financed with a mix of grants, loans, and budget allocations. As a good example the wastewater treatment pant in Klapéda might serve. It receives allocations from the State and municipal budgets, grants from Sweden, Finland and the EU PHARE programme. These funds are supplemented with a loan from World Bank. By allocating funds for the environment, the PIP follows the investment priorities of the National Environmental Strategy. Thus, the construction of wastewater treatment facilities remains the highest priority. Furthermore, the obligations deriving from the Helsinki Conference, 1992, on the protection and use of trans-boundary watercourses and international lakes, require the construction or improvement of wastewater treatment facilities in 5 large cities of the country.

Extra-budgetary funds consist of the State Nature Protection Fund, which includes environmental penalties and sanctions and is managed by the ministry of Environment, the municipal environmental protection funds (includes pollution charges) and the Environmental Fund for Investments. The latter uses loans, which are granted by banks according to national regulations and has developed transparent rules on granting loans with the help of USAID. Foreign sources cover 57% of the 1997-1999 environmental investment programme. Before 1996, foreign assistance was primarily project-related. Later, when commercial interest rates became more affordable, loans prevailed. So, 80% of these funds were committed on investments (financed by loans and grants) and 20% on technical assistance (financed by grants only). Wastewater treatment projects were financed by environmental funds and municipal grants, but the largest share was financed by enterprises, especially for projects with improve technological processes (EPR, 1998).

7.10 Information sources (Topic j)

The main information sources on wastewater are publications of the European Union, the OECD, the UNECE: "Convention of the Protection and Use of Transboundary Watercourses and International Lakes", and the UN/ECE "Environmental Performance Reviews". While in Accession countries the political situation is quite stabile, in some other transition countries the government has chanced after elections, which reflect the structure of the ministry dealing with water/wastewater.

According to the available sources the following institutions/ministries could be contacted in order to get access to information related to water management/wastewater:
The addresses are taken from the internet-page of UN/ECE "Convention on the Protection and use of Transboundary Watercourses and International Lakes": www.unece.org/env /water (from the ECE-homepage, choose "Environment and Human Settlement", then "Water", then

"Addresses", and then "National focal points"). The addresses are regularly updated and might serve as an focal point to find the right information and people.

Albania
Committee of Environmental Protection and Preservation
Ministry of Health and Environment
Tirana
Fax: (355 42) 652 29

Armenia
Department of Protection of Water Resources
Ministry of Nature Protection
35, Moskovian Street
Yerevan 375002
Fax: (3742) 15 18 40

Azerbaijan
State Committee on Ecology and Nature Conservation
Istiglatyyat str.31
370001 Baku
Fax: (99412) 92 59 07

Belarus
Ministry of Natural Resources and Environmental Protection
10, Kollektornaya str.
200048 Minsk
Fax: (37 5172) 20 7261 / 4771

Bulgaria
Ministry of Environment and Water
Bulv. Maria Luiza 22
1000 Sofia
Fax: (3592) 980 96 41

Croatia
State Water Directorate
220, Av. Vukovar
41000 Zagreb
Fax: (385 1) 61 51 821

Czech Republic
Department of Water Protection
Ministry of Environment
65, Vrsovicka
100 10 Prague 10
Fax: (4202) 67 31 03 08

Estonia
Environmental Protection Department
Ministry of Environment
24, Toompuiestee
0100 Tallinn
Fax: (372 62 62 801

Georgia
Ministry of Environmental Protection
68a, Kostava str.
380015 Tbilisi
Fax: (995 32) 94 36 70

Hungary
Ministry of Environment
1011 Budapest
Fax: (361) 201 2846

Latvia
Ministry of Environmental Protection and Regional Development
25, Peldu iela
1006 Riga
Fax: (371 7) 820 442

Lithuania
Environmental Protection Ministry
9, A. Juozapavi iaus
2600 Vilnius
Fax: (370 2) 72 84 24

Poland
Water Resources Department
Ministry of Environmental Protection, Natural Resources and Forestry
52/54, ul. Wawelska
00-922 Warsaw
Fax: (48 22) 825 47 61

Republic of Molodva
State Ecological Inspection
Ministry of Environment and Territorial Development
9, Cosmonautilor Str
2005 Chisinau
Fax: (373 2) 22 07 48 / 27 74 86

Romania
Department of Water
Ministry of Waters, Forests and Environmental Protection
12, bd. Libertatii, Sector 5
Bucharest
Fax: (401) 410 20 32

Russian Federation
Ministry of Natural Resources
3B, Orlikov Lane
107 130 Moscow
Fax: (7 095) 208 1177
(7 095) 208 4364

Slovakia
Department of Water Protection
Ministry of Environment
1, Nam. L. Stura
81 235 Bratislava
Fax: (4217) 59 56

Slovenia

Ministry of Environment and Regional Planning
48, Dunajska
1000 Ljubljana
Fax: (38 661) 178 7422

Republic of Macedonia
Ministry of Urban Planning, Construction and Environment
14, Dame Gruev
91000 Skopje
Fax: (389 91) 117 163

Ukraine
Ministry for Environmental Protection and Nuclear Safety
5, Khreshchatyk str.
252601 Kiev
Fax: (38044) 228 7798

The former European Water Pollution Control Association (EWPCA), renamed to European Water Association (EWA), is an association of professional European organisations and individual members - within the water/wastewater and solid waste sector - providing a forum for views and interests of professionals and technicians in the sector. EWA has published a list of there National Representatives in the internet: http://www.ewpca.de , which includes addresses of members from Hungary, Croatia, Slovakia, Russia, Bulgaria, Poland, Slovenia, Yugoslavia, Czech Republic, Latvia, Estonia and Lithuania.

Several transition countries have their own homepage for presenting environmental matters on the ministerial level, where also information on wastewater can be gathered (Maass, 1999). Examples are:

Estonia
www.envir.ee , paragraph 8: surface water (National Environmental Strategy)
www.envir.ee/ehp (wastewater legislation).

Poland
www.mos.gov.pl (legislation, publications: The State of the Environment in Poland).

Slovenia
www.slgov.sl/mop/vsebina/angl/index.htm (legislation)

Czech Republic
www.env.cz (State of the Environment in the Czech Republic, Water in the Czech Republic, paragraph 4: Water in User's Systems).

Hungary
www.gridbp.meh.hu/indexa.htm (State of the Environment, paragraph: Water , Pollution of surface water)
www.mav.hu/khvm (Page of the Ministry of Transport, Communication and Water).

European Union, DG I,
www.europa.eu.int/comm/dg1a,
(Progress of the Accession Countries).

7.11 Case studies (Topic k)

7.11.1 The Russian Federation

Like many other countries in transition, the Russian Federation faces many problems in the field of market oriented economy, efficient institutional and legal frameworks and financial transparency. Since the break-down of the former Soviet Union in the beginning of the 1990s, the decline in economic activity continues, partly due to political and legal uncertainties. The reduced economic activities have also an impact on the use and pollution of water resources. Many water bodies in the country are highly affected by man-made pollution. To improve the situation, huge financial and material resources are necessary, which do not exist for the time being. To move the process along, a stepwise improvement of the water quality and priority setting for investments would be necessary. The existing water management system still lacks efficiency, which makes it difficult to improve water quality. Among the reasons are the very stringent standards, which are difficult to implement and enforce. These standards are valid for wastewater, which is discharged into the sewage network and discharged wastewater after treatment. The adaptation of the existing water law to more efficient standards used in European market economy countries would be the first step in this direction. At present, two main water laws are ruling water management in Russia. These are the so called "Water Codex" which lays down obligations regarding the use and protection of the water resources (adopted 18 October 1995) and the law regarding the protection of surface water against pollution (adopted in 1991).

Freshwater quality

Despite all efforts, the overall water quality of freshwaters has improved little during the last decade. Nevertheless, the discharge of wastewater into water bodies was reduced by approximately 30%, from 76.4 to 55.7 km^3/year. The amount of polluting substances in wastewater also decreased, for several parameters even up to 50 %. According to the State Water Inventory, substances most often exceeding the maximum allowable concentrations in discharged wastewater are:

- Nitrate- ammonium ($N\text{-}NH_4$) in the basins of the rivers Volga, Terek, Amur, Western Dvina and Lake Baikal,
- Copper in the basins of the rivers Ob, Kuban and Neva,
- Phenols in the river basins of Yenisej, and Western Dvina,
- Phosphorous in the basins of the river Don, Ural, and Dnjepr,
- Oil products, organic substances, nitrite, iron, zinc and manganese in the rivers mentioned above.

In 1998, the most polluted river basins were those of the rivers Neva and Western Dvina, followed by the Volga, the Northern Dvina and the Lena river (see figure 7.5a and 7.5b). Not included in these statistics are estimates about non-point sources of pollution, like impact on water quality from agricultural activities, urban run-off, transport and others. Furthermore, in the given statistics no accidental water pollution is included, or diffuse irrigation water. In 1998, the amount of water used for irrigation was 7.3 km^3, of which more than 50% was used in the river basins of Kuban, Terek and Don. A large part of this irrigation water is polluted by toxic chemicals as well as nitrogen and phosphorus from fertilisers. The exclusion of the polluted irrigation water from statistics leads to a distortion of the amount of discharged polluted wastewater in the mentioned river basins.

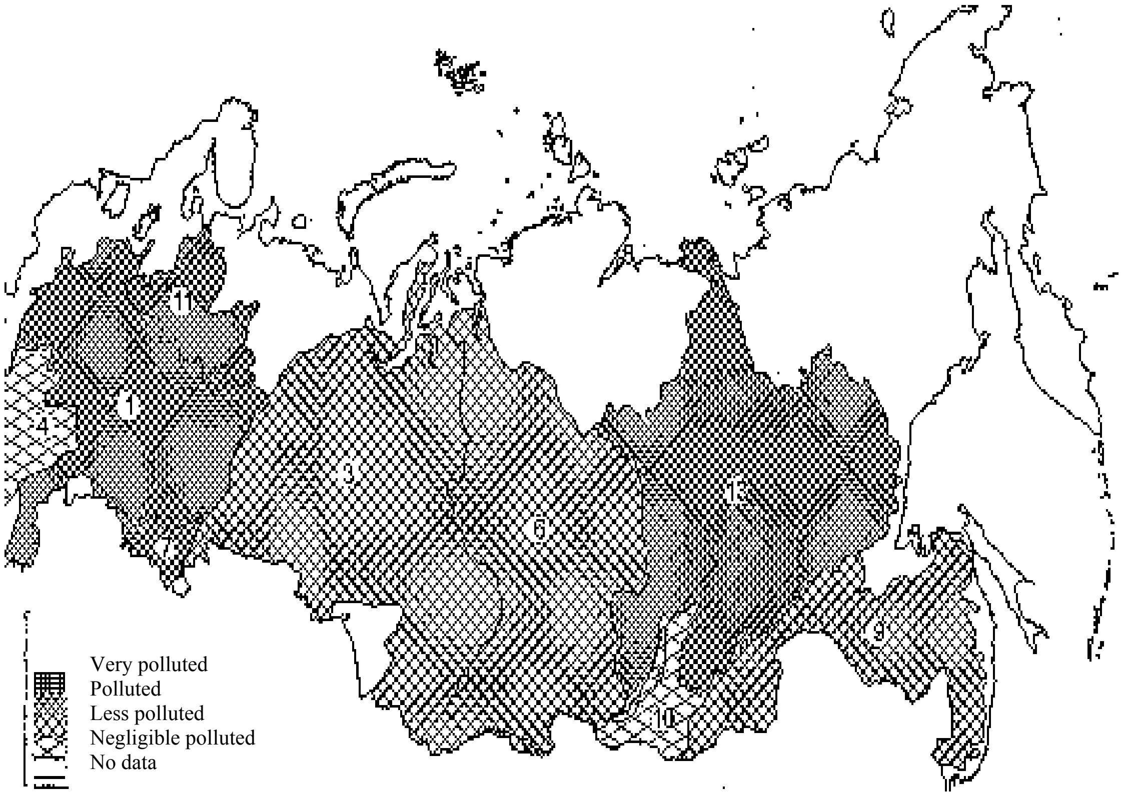


Figure 7.5a: Pollution degree of the 14 main river basins in the Russian Federation (1998)

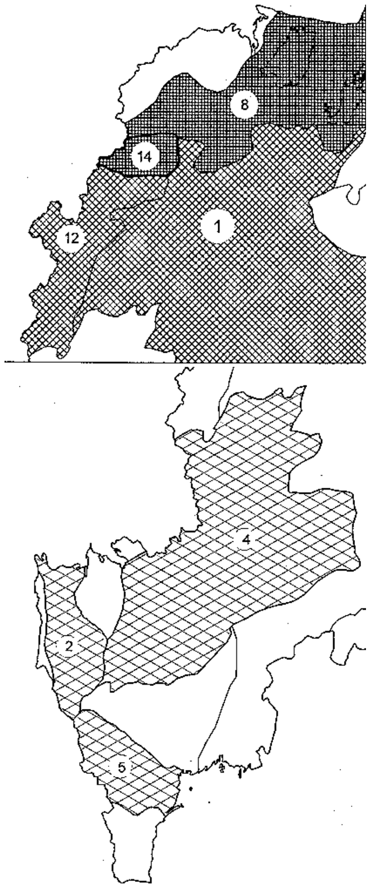
Pollution sources

Insufficient or not treated wastewater is a serious pollution source for natural water bodies. According to data of the State Water Inventory (table 7.11), 22 km^3 of such wastewater (12.3% of all discharged wastewater) was discharged in 1998 into surface water.

Another pollution source is the diffuse input of polluted water from settlements without sewage network, from streets and related traffic, from sealed surfaces in enterprises and from areas with agricultural activities. Diffuse sources of pollution generally contribute more than 50% to the total pollution of water bodies (Zhmur, 1999). More specifically, the share of various substances is as follows: 60-80% nitrogen, up to 80% pesticides, 70% oil products, 80%suspended matters and 20% organic substances.

A further strong pollution source is sewage sludge, produced by wastewater treatment plants. In Russia, the annual mean amount of sludge production is about 80 million m^3 (with a humidity of 96-97%), which equals an amount of dry substance of about 3 million t/year.

Reuse, composting or incineration of sludge is not common. The sludge contains a high amount of metals and other hazardous substances. Thus, its treatment becomes very expensive. Almost all sludge from treatment plants is untreated and disposed off on land on sludge fields. Because of the size of the country, there is enough space for new sludge fields. According to the law, closed or used sludge fields have to be regularly monitored, which is however not always done under the present economic conditions. During rainfall and snow melt, the sludge may be washed away and can adversely impact unpolluted areas.



Number and names of the river basins in Russia:

1. Volga
2. Kuban
3. Ob
4. Don
5. Terek
6. Yeniseji
7. Ural
8. Neva
9. Amur
10. Lake Baikal
11. Northern Dvina
12. Dnepr
13. Lena
14. Western Dvina

The pollution degree was calculated as relation between the mean of the concentrations of 6 pollutants in wastewater and the maximum allowable concentrations of water standards for fishery. The 6 pollutants are: organic matter, N-NH4, Fe, P total, nitrogen and oil products.

Figure 7.5b: Pollution degree of the 14 main river basins in the Russian Federation (1998)

Monitoring and control of water resources

Monitoring and control of water resources is carried out by different State agencies at all administrative levels (federal, regional, local levels).

Monitoring of surface waters, for example, is carried out under the auspices of the Ministry of Natural Resources and the Federal Service of Hydrometeorology and Monitoring of the Environment (the latter entity only for marine and surface water monitoring), together with other State agencies responsible for environmental protection. The geological division of the Ministry of Natural Resources is mainly responsible for groundwater monitoring. Other State agencies dealing with water monitoring are the State Committee on Environmental Protection (man-made impact on waters), the State Committee on Fishery (aquatic life protection) and Ministry of Health (drinking water, mineral water and recreational waters). The monitoring on surface waters is carried out on the federal, regional (according to river basins), territorial and local level jointly with all the relevant administrations on each level.

The control of water resources is carried out by executive agencies of the regions, by the Ministry of Natural Resources, by specialised State agencies for environmental protection and other relevant agencies. Under the auspices of the above Ministry, three different entities are responsible for water control including the State control of the use and protection of water bodies being part of the Ministry; the State control unit of the territories (in the frame of river basins); and the State control units in the frame of the 89 regions in the Russian Federation. The Senior staff of these bodies act at the same time as inspectors for their area of responsibility. There are 289 water control inspectorates, equipped with their own laboratories. Usually, they take samples twice a year as far as 500m downstream of effluent discharge points, depending on the volume of the wastewater discharge.

Responsibility for the control and protection of ground water is jointly shared by the State control agency for the use and protection of water bodies and the State geological control agency (both belonging to the Ministry of Natural Resources), and the State control for sanitation and epidemiology of the Ministry of Health.

The State inspectors are entitled to control water users at any time, to give orders to these water users, and to control the implementation of given orders. Moreover, they have the power to cancel the water use licence, and in the worst case to close down enterprises or entities which do not respect the laws.

Water quality standards

In Russia, several water quality standards exist which apply to various uses of the water body. The most stringent water quality standards are those for fisheries. Almost all wastewater discharged into water bodies has to correspond to water quality standards for fisheries, which are stricter than those for human consumption. For example, all discharged wastewater should by law not exceed BOD_{20} of 3 mg/l, NH_4 ammonium 0.39mg/l, oil products 0.05 mg/l and Phosphate 0.15 mg/l.

These standards for fisheries are also valid for industrial wastewater discharged into municipal sewage systems. Industrial enterprises have to ensure the quality of their wastewater meets the water standards of the fishery before being discharged into the municipal system. To do so, these enterprises have to spend a huge amount of money on their pre-treatment systems to make improvements regarding construction and level of technology of their systems. Furthermore, enterprises have to pay fines for exceeding water quality standards, which are not adapted to the existing economic situation (inflation, costs and prices etc.).

Sewage network

By law, all newly built houses or enterprises have to be connected to a sewage system. Most towns are equipped with centralised sewage networks, so the implementation of this obligation is not a problem. Villages mostly do not have networks, the people discharge their grey-water into nature and the black water into pits. Industrial and agricultural enterprises must have pre-treatment facilities by law, before discharging into municipal sewage networks or into surface waters. The operation and efficiency of such pre-treatment facilities always depends on the financial capacities of the enterprise.

Currently, the extension or construction of a sewage network in a settlement depends mostly on the financial resources and the priority setting of the local government and not primarily on the size of the population, or the amount and concentration of the wastewater. Only the Sanitation-Epidemiological Inspection of the Ministry of Health has the power to order the construction or extension of a sewage network as well as the connection of enterprises or settlements to an existing one.

Water use and wastewater discharge

In 1998 the volume of wastewater discharged into surface water was reduced by 3.5 km^3 as compared to 1997 (Table 7.11). This reduction was the result of a reduced use of water for irrigation and for industrial production, because of the further close down of industrial and agricultural enterprises. In 1998, only 13.7% (2.5 km^3) of the produced wastewater, which requires treatment, was treated according to the standards. The reasons were overloading and low efficiency of the operating wastewater treatment plants (State Water Inventory, 04/1999).

Table 7.11: Water use and wastewater discharge of the Russian Federation in 1997 and 1998 (million m3)

Parameter	1997	1998	% to 1997
Water use			
Number of water users (enterprises)	53970	53504	99
Total water use	70176	66192	94
Municipal drinking-water use	13602	13697	101
Industrial use	38437	37027	96
Irrigation	9063	8979	99
Agricultural use	2911	2169	75
Other water use	6110	4170	68
Wastewater discharge			
Total wastewater discharge	71662	71226	99
Wastewater discharge into surface waters	59277	55753	94
Of which: polluted water	23043	21985	96
Of which: without any treatment	6813	6175	91
Insufficient treatment	16231	15838	98
Wastewater , which do not need any treatment	33625	31218	93
Treated according to the standards	2609	2522	97
Of which biological treated	2100	2000	95
Capacity of treatment plants	31275	30705	98

Source: Information bulletin of the State Water Inventory, No. 01/99 of the Ministry of Natural Resources

Data on water abstraction and wastewater discharge are also available for all 89 administrative regions of the Russian Federation.

The characteristics of wastewater in 1998 for the Russian Federation are shown in table 7.12. Data were taken from the information bulletin of the State Water Inventory, No. 04/99.

Table 7.12: Wastewater characteristic for 1997 and 1998 of the Russian Federation, (1000 t)

Parameter	1997	1998
BOD	401.5	374
Oil products	7.8	6.3
Suspended solids	-	608
P total	31	30.1
Nitrate-ammonium	97	90
Nitrite	6.7	7.0
Phenol	0.06	0.06
Surface-active synthetic substances	-	3.3
Iron	19.6	12
Manganese	0.6	0.7
Copper	0.21	0.16
Zinc	0.68	0.56

In 1998, 39% (21,985 km^3) of all wastewater, discharged into surface water, was polluted. Of these polluted wastewater 31% came from industry and 55% from municipalities. In industry the largest amount of wastewater is produced by the energy and heating sector, the chemical and oil producing industry, the paper industry and black metallurgy.

In general, since 1990 the volume of discharged wastewater decreased (see Figure 7.6). Only in some economic sectors an increase of polluted wastewater occurred which is linked to the fact that wastewater which was not treated in the past now belongs to a wastewater category which is subject to treatment.

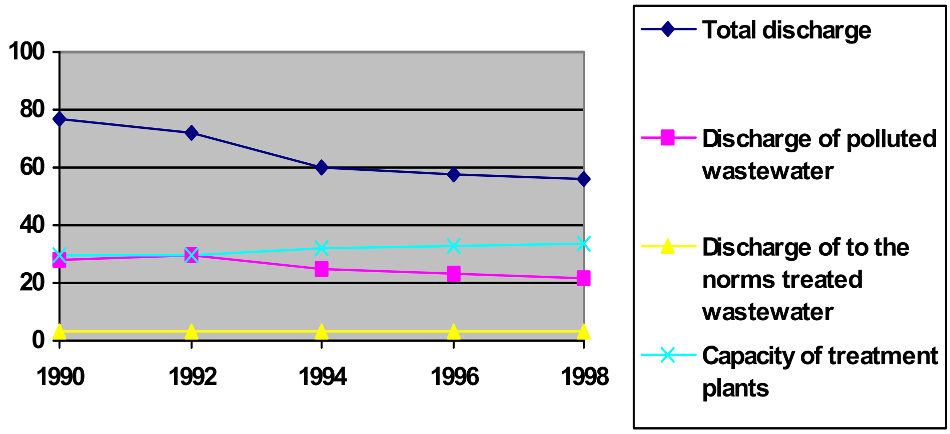


Figure 7.6: Overview of the discharge of wastewater in the Russian Federation for 1990-1998

Source: State Water Inventory, No. 03/99 of the Ministry of Natural Resources.

Treatment

In Russia, in 1998, 55.7 km^3 of wastewater (including water from mines and irrigation) was discharged into surface water. Out of this amount, about 33% (18.3 km^3) received treatment. Out of this 33% treated wastewater, only 13.7% was treated according to the standards, i.e. by biological treatment (State Water Inventory, 04/1999). Furthermore, most of the Russian municipal wastewater treatment plants were built 20-30 years ago. The aim was to achieve BOD and SM values of 10-15 mg/l in wastewater. During biological treatment, the content of heavy metals is reduced by about 40-80%, for oil pollution about 20-80%, for surface active synthetic substances up to 50%, for $N\text{-}NH_4$ and phosphorus by 25-30% etc. At present, the efficiency of the treatment plants is however not always satisfactory because of overloading, difficulties in maintenance and reconstruction, etc. Thus, the projected treatment level can not always be reached (Zhmur, 1999).

Quite often, the biological treatment already includes some nitrogen and phosphorous removal, as well as the removal of oil products. In the tertiary treatment, after filtering, the BOD_{20} will be reduced from 15-20mg/l to 6-8 mg/l, which is still higher than the 3mg/l demanded by law for discharge into surface water. In smaller rural settlements more and more compact pre-build treatment facilities are used.

As it was already the case in the former USSR, industrial enterprises are obliged by law to build pre-treatment facilities. Whether these pre-treatment facilities are used depends mostly on the financial situation of the enterprise. There is a lot of research to improve treatment processes, but the practical implementation of R&D results is still to costly. In previous times, there was a trend to centralise wastewater treatment and build a large treatment plant per region. Today, wastewater treatment will be decentralised, depending on the main sources of pollution and on the degree of pollution. A growing problem is the oil pollution in cities as well as in areas where the oil is withdrawn.

Storm-water management

Only a few big cities in Russia have separate rainwater systems. St. Petersburg is equipped with a combined system, but in newly built areas a separate system has been introduced. In other Russian cities, separate systems are only available in smaller parts of the city area. As a general rule, storm-water receives only mechanical treatment. In some cases oil products are taken out by membrane filtration.

Reuse
Treated wastewater is not reused, neither for irrigation, gardens, parks etc. In the summer month, some grey-water of rural households is used for irrigation of gardens and green areas around holiday homes. For the time being, freshwater is less expensive than treated wastewater, so people mostly use freshwater for gardens, parks and sport areas.

Sludge is not yet reused or incinerated, but there are some pilot projects running. Only a small amount is used in forestry as fertiliser. Human excreta is disposed on land, sometimes staying in the pit, which will be closed down. Animal excrement is sometimes used as fertiliser on fields, depending on the transport capacity of the agricultural enterprise. Chemical fertilisers were in the past always available being less expensive and having a better storage capacity. Now most of the former large agricultural enterprises (kolchos) do not exist anymore. Private enterprises often do not have the transport capacity to carry the composted sludge to remote fields. Disposal fields and the distribution as fertiliser in rural areas are often not controlled.

The use of cooling water has also declined during the last years. It is mostly used in closed cycles and only 10-15% of the cooling water is being discharged. The high salt content of this water requires treatment by law. Treated cooling water is often reused as cooling water or for the irrigation of nearby gardens and holiday homes.

Financing
The-polluter-pays-principle is used in Russia. Because of the high fees and penalties for exceeding the water quality standards, most of the resources were invested into industrial pre-treatment (tertiary treatment) of wastewater. Before a pre-treatment facility is approved by the administration, it has to be projected in such a way that it achieves the stringent water quality standards. In practice, however, these standards will rarely be achieved by pre-treatment facilities.

Most enterprises get exceptional contracts which are limited in time within which they are allowed to exceed the pollution standards to a certain extent for selected parameters. If the enterprises does not comply with the contact conditions, they have to pay penalties to the Ecological Funds, of which 50% goes to the Federal and 50% to the Regional Ecological Fund. These funds are one financial basis for modernisation and construction of new municipal treatment plants. An appropriate financial stimulation for enterprises to improve technology and install environmentally- friendly technology is lacking. An attempt to switch gradually to international standards for Water Quality, like those of the European Union, would also encourage foreign and national investors to strengthen the economy in the country.

Furthermore, enterprises have to pay for water abstraction and wastewater treatment to the responsible State enterprise Vodokanal. The price depends on the region and the river basin where the enterprise is situated. For water abstraction, the costs are between 39 - 104 Rubels/1000m^3 and for wastewater discharges between 4,5 - 17.7 Rubels/1000m^3.

The urban and rural population has to pay for centralised drinking water supply (cold and warm water), heating and wastewater collection/treatment. Prices differ throughout the country and can be up to 30% of the apartment rent. Until now these expenses for centralised services show little impact on the drinking water demand for households, which is still slightly increasing. In rural areas with decentralised systems (water abstraction from wells) people pay for freshwater abstraction and energy. Not all households are able or willing to pay for these services.

To further stimulate the rational water use, a new reform was introduced in 1999. The expenses for water and heating for the population will further increase (depending on capita/family income) and the expenses for enterprises will decrease to encourage economic growth. Today about 80% of the Russian population pays for water and heating. To increase that percentage and to make payments more reliable, water-meters will be stepwise introduced. At present, water-meters exist mostly one per house and every household pays an average. In some buildings the upper floors do not always get water due to a lack of water pressure. To stimulate the rational use of water per household, every apartment will get its own water-meter in the future. First this will be implemented for Moscow and some other industrial centres.

7.11.2 Wastewater management in Moscow

Sewage network
Moscow, the capital of the Russian Federation, has about 10 million inhabitants and is the largest city in the country. The whole city of Moscow, including buildings and infrastructure in the forest-park around the city, and some agglomerations around Moscow (all together more then 80 000 ha) are served by sewage networks. The networks are owned by the State enterprise Vodokanal and have a length of more than 7000 km. Moscow benefits from a separate system for sewage and storm-water. In average, the network system is installed at a depth of 5m and equipped with 125 pumping stations and 2 large aeration stations. Also newly-built parts of the city have separate systems.

The total capacity of the sewage network is more than 9 million m^3/24 hours. The average capacity per 24 hours is about 6 million m^3 of wastewater. The network is divided into two systems - Kurjanovsk and Ljuberezk - depending on the serving aeration station. The receiving wastewater is of municipal and industrial origin and is treated at four treatment plants (see table 7.13).

Wastewater treatment technology in Moscow
All wastewater which enters treatment plants is biologically treated. In the Zelenograd and Kurjanovsk treatment plants the wastewater is pre-treated with the help of filters, which decrease the amount of suspended matters and organic substances. About 3000 industrial enterprises discharge their wastewater into the sewage network, of which 50% is not pre-treated. Industrial wastewater makes up about 15-20% of the wastewater entering the treatment plants in the city. But the treatment plants are not equipped with facilities to remove typical substances of industrial wastewater neither to remove nitrate and phosphorous. Only the new treatment plant at Yushnobutovsk benefits from a removal of carbon, nitrogen and phosphorous and final disinfecting thorough ultra-violet light. Disinfection is also done at two other treatment plants: Zelenograd (100%) and Kurjanovsk.

The annual amount of sludge, produced by all four treatment plants, is about 10 million m^3. All sludge goes through methane tanks. Further sludge treatment is carried out by dehydration through membrane filter presses, or “naturally” dehydrated on sludge fields. After dehydration, the sludge (about 10 million m^3) is transferred to special areas called “polygons”, which are planned to be situated on already existing sludge fields (about 800 ha). A present, all plants are equipped with facilities, to dehydrate all generated sludge mechanically.

Table 7.13: Capacities of the wastewater treatment plants of Moscow

Name of the plant	Years of operation	Capacity (1000 m3/24 hours)				
		projected	actual			
			1990	1995	1998	1999
Kurjanovsk	1950, 1976	3125	3486	3154	3240	2902
Ljuberezk	1963,1986, 1997	3000	2046	2387	2512	2607
Ljublinsk	1938, stopped working in1996		461	368	-	-
Zelenograd	1966, 1980	90	101	111	104	95
Yushnobutovsk	1999	80	-	-	-	38*
Total		**6295**	**6094**	**6020**	**5856**	**5642**

Note: * Started operating in March 1999.

Wastewater characteristics for the city of Moscow

The volume of generated wastewater considerably decreased during the last decade. However, the pollution of the incoming wastewater only slightly decreased during the same period of time (Table 7.14).

In Moscow's separate sewage system all municipal and industrial wastewater is collected and treated at the treatment plants. Stormwater is not always treated (if so only mechanically), more often it is directly discharged into the water bodies of the city.

Table 7.14: Pollution trends of incoming untreated wastewater per treatment station

Parameter	Concentration (in mg/l)											
	Kurjanovsk			Ljublinsk			Ljuberezk			Zelenograd		
	1990	1995	1998	1990	1995	1998	1990	1995	1998	1990	1995	1998
SM	181	178	170	144	99	-	178	161	142	219	205	176
BOD_5	172	157	118	157	132	-	160	126	113	173	154	143
N total	28	23	24	45	23	-	29	22	25	-	-	-
Phos-phates	-	1.9	1.6	-	2.3	-	-	1.5	2	-	2.1	2.7

The following table (table 7.15) shows the wastewater pollution before and after treatment in 1998 per treatment station and the comparison between Russian and European Union water quality standards.

Table 7.15: Wastewater pollution before and after treatment in 1998

Parameter	Concentration (in mg/l)							
	Kurjanovsk		Ljuberezk		Zelenograd		Standards	
	Before	after	before	after	before	after	Russian	EU
SM	170	11.9	142	7.3	176	2.9	>0.75	35
BOD5	118	9	113	3.8	143	2.2	3	25
N total	24	18	25	24	-	-	-	10
P total	2.8	2.3	4.9	3	5.3	4.6	-	1
Phos-phates	1.6	1.2	2	2.4	2.7	2.9	0.2	-

The same table is given for the year 1999, including the new treatment plant Yushnobutovsk (table 7.16). This treatment plant was designed and built by a German company under consideration of European Union and national Russian water quality standards. In the near future a similar treatment plant will be built in Zelenograd, with a planned capacity of 140 000m3/24 hours.

Table 7.16: Wastewater pollution before and after treatment in 1999 per treatment station

Parameter	Concentration (in mg/l)							
	Kurjanovsk		Ljuberezk		Zelenograd		Yushnobutovsk	
	before	after	before	after	before	after	before	after
SM	179	11.8	177	7.1	169	2.8	132	2
BOD5	115	8.6	126	3.8	134	1.8	107	3.3
N total	24	17	26	17.8	-	-	14	3.4
P total	3.5	2.8	5	2.7	5.2	4.3	4.7	0.64
Phos-phates	1.8	1.1	2.3	1.9	2.2	2.3	2.9	0.53

Source: All data were provided by Vodokanal Moscow.

Sludge treatment and use

In Moscow and some other big cities, sludge undergoes thermo- treatment in methane tanks and is disposed off after filtering (filter presses). The methane is locally used for heating purposes. In the 1950s, methane gas was widely used for apartment heating and special car engines. Unfortunately, this development was stopped after some years. Today the sludge is dehydrated and disposed onto sludge fields. At least around Moscow, the sludge fields are specially equipped with impermeable layers (liners) and monitored. A small percentage of the sludge is used after composting as humus for gardens. In the whole country incineration of sludge is not common, because of the costs for specialised equipment. Only in St. Petersburg a small amount of sludge is incinerated. The incineration will not be more widely used in the near future.

Wastewater reuse in Moscow

Untreated wastewater is not used at all. Biologically treated wastewater is used at the treatment plants for technical purposes, like cleaning activities in the plants. The treated water of the Kurjanovsk treatment plant is used in some enterprises for industrial water supply.
About 10% of dehydrated sludge is used as fertiliser for the forest-park around the city.

Financing of wastewater treatment

The State enterprise Vodokanal is responsible for all water services, including wastewater collection, treatment and disposal. The enterprise is owned by the government of Moscow, but is financially relatively independent. The main financial source is the water users, which have to pay for water services and heating. They serve three categories of water users, which have to pay different amounts of money:
1) population with 0.63 Rubels/m3,
2) municipal enterprises and institutions with 4.90 Rubels/m3,
3) industrial enterprises with 6.75 Rubels/m3.

Vodokanal owns and operates the water meters for the population and industry. At present about 35 000 water meters are operating in the city. New constructions for water supply and wastewater treatment are paid by the government of Moscow, but reconstruction and modernisation are paid by Vodokanal itself. Moscow benefits also from foreign credits, like for the construction of a new wastewater plant in Yugo-Sapadno, financed jointly by the European Bank, France and the government of Moscow. Outside Moscow, both new constructions and reconstruction work are mostly paid by local governments and owners of enterprises.

Public education in Moscow

The interest of the population on environmental matters has increased, but economic issues still have priority. Nevertheless, NGOs and State organisations publish papers, like the "

Journal of natural resources", which inform the population about many environmental issues. Vodokanal is quite active in the water sector. The enterprise has its own small "Water museum", explaining the history and development of water supply and wastewater treatment in Moscow for children and adults. The visitors can also participate in specially organised visits of water works and treatment plants.

Vodokanal Moscow has its own old "Mercedes-bus", a gift from the town of Berlin, which is drives through the town and attracts school classes as well as adults with information about drinking and wastewater. Furthermore, school excursions to water works and treatment plants are organised, and different types of courses on water matters for children carried out (like "Safe the water", "Rational use of water", "The ordinary wonder-water", etc.). Vodokanal also publishes papers for children such as "Arguments and facts for children" on water problems in Moscow. There are plans for wide distribution of this information throughout the whole country.

Education
The qualification of the personal working in treatment plants has improved in the last few years, because of "newcomers" from the military sector (wastewater treatment plants in the military sector were in the past often better operated and maintained than those in the civil sector), better education and a better reputation attributed to the job.

For high level managers the University for Construction in Moscow is the leading training centre. For further training, this university together with Vodokanal and the State Committee for Geology (Vodgeo) make post-graduated and specialised studies possible. At the operational level, Vodokanal has a special training centre for technicians and operators of treatment plants. At all training levels Russia gets support from the Netherlands, Germany and other countries, to provide training for other Russian cities also.

Information sources
For further information the following addresses could be useful**.**

VODGEO
VODGEO is the short title for the Research and Engineering Institute for Water Supply, Sewage Systems, Hydraulics and Hydrogeological Engineering in Moscow. The Institute is the leading national organisation for the protection and the rational use of water resources. In the area of wastewater management, the institute is carrying out research on treatment methods for wastewater and sludge, it is developing new construction types for mechanical, biochemical, chemical and physico-chemical treatment facilities for highly concentrated industrial effluents. The institute works also on industrial wastewater and sludge reuse methods. The contact address is: wodgeo@aha.ru
Tel.: 007 095 245 98 50, Fax: 007 095 245 97 80.

Ministry of Natural Resources
The Ministry of Natural Resources is the leading entity for water management and is divided into two parts; the geological (groundwater) and the surface water management parts. The water management part includes the water service division, the water management division and the Committee for Natural Resources. There main tasks are the water management of 17 large river basins (surface water quality and quantity), licensing of water abstractions, monitoring, operation and safety of reservoirs, water protection, water supply and wastewater treatment, the development of the water fund and the work with agreements on international watercourses.
Contact address: Fax: 007 095 208 1177 / 207 4364

State Water Inventory (also known as "Cadaster")
The State Water Inventory is an agency of the Ministry of Natural Resources, responsible for collecting statistical information on water abstraction and use as well as on discharge of waste water of from industrial and agricultural enterprises in the Russian Federation (more than 60`000 enterprises). The agency collects and publishes information on freshwater and marine water for the whole country, for 14 main large river basins (down to the local level). Its work is financed through the State budget.
Contact address: Fax: 007 095 124 6215, e-mail: gvkr@vodinform.msk.ru

Vodokanal
Vodokanal is a State-owned company and at the same time the owner and responsible company for the construction, operation and maintenance of the sewage network and the wastewater treatment stations in the country. It is also responsible for sludge treatment and disposal/reuse. Vodokanal enterprises exist in Moscow and all the administrative regions.
Contact address: e-mail: Vodokanal Moscow: mgpmuk@dol.ru

7.11.3 The Republic of Moldova

The Republic of Moldova emerged in August 1991 as an independent State after the break-up of the former Soviet Union. It is a small (338000 km^2), landlocked country between Ukraine and Romania with a population of 4.3 million people. In 1997, a political memorandum was signed which granted the territory on the left bank of the Dniester River (Transnistria) a certain autonomy. This was the result of an armed conflict between separatist movements in Transnistria and the central Government. All statistics after the year 1997 exclude this part of the country.

Since the beginning of the 1990s, the industrial and agricultural production of the country has decreased significantly through political, institutional and legal uncertainties tied to the beginning of the consolidation of the new Republic. At present, in most industrial branches only 10% of enterprises are operational as compared to 1990. Small and medium-sized enterprises are not supported by the newly introduced reforms, by laws or the Government.

The major problem in Moldova – and this is also true of wastewater treatment - is the shortage of energy. Energy is no longer imported for free from Russia. This causes immense problems as (and this was a usual fact in the former Soviet Union) the whole economic sector is still extremely energy-intensive. Today, Moldova does not have enough resources to finance energy imports. The country itself has no oil, gas or other energy resources.

In the 1990s (from 1990 to1998), the generation of wastewater declined, as a consequence of the decline of industrial and other production, by about 8% from 269.4 million m^3 to 212.6 million m^3 per year. Accordingly, the concentration of hazardous and other substances in municipal wastewater also declined (see table 7.17).

Table 7.17: Characteristics of wastewater for 1990, 1995, 1998 for the Republic of Moldova (1000 t)

Parameter	1990	1995	1998*
Suspended matter	5340	2810	2400
BOD 20	4490	2190	2040
N tot	2153	1808	1445
P tot	179	96.3	84.7

Note: * The year 1998 does not include the territory of Transnistria.
Source: APA-canal Moldova.

In the country, the amount of discharged municipal wastewater has slightly increased during the last years (1995: 71%, 1998: 74%). However, the amount of discharged industrial wastewater has declined. These data exclude the territory of Transnistria.

Sewage network

Like in all former Soviet Union Republics, the percentage of urban population connected to sewage networks is very high. In 1998 most urban households were connected to the sewage system, with the highest percentage in the capital (about 97%). Un-connected urban households discharge their wastewater into pits, which are cleaned by APA-Canal before their discharge into the municipal sewage network. These wastewater are being treated in municipal plants.

In Moldova, all cities are equipped with combined sewage networks. The Republican urban network has a length of about 1814 km and brings about 93% of the municipal wastewater to treatment plants, only 7% is discharged untreated into nature.

Stormwater is not separately collected in the capital Chisinau or elsewhere in the country. It enters the water bodies directly.

In rural areas, the population is using pits and sometimes small treatment facilities, which are controlled by the Water Inspections. Data about rural sewage collection is not available**,** but most of the rural wastewater does not undergo any treatment.

Water losses in the drinking and sewage system are high (50-70%), because of limited financial capacities to reconstruct the systems. These consequences of losses, together with low pressure in the networks, constitute a potential hazard for human health.

Treatment

According to the 1998 data given by "APA-canal Moldova", 99% of all urban municipal wastewater is biologically treated. Biological treatment includes aeration tanks, the use of activated sludge and biological filters. There is no tertiary treatment (removal of nitrogen and phosphates) available. Treatment facilities are available in 35 cities. However, they are old and sometimes in a desolate state, meaning efficiency is limited. Another factor hampering the treatment process is the frequent energy cuts. Furthermore, the treatment plants do not work to full capacity as the amount of wastewater entering the plant is far below the original design level.

In rural areas, simple mechanical and biological treatment facilities or septic tanks are used in treating waste. Rural households discharge greywater into nature, and blackwater into pits. The pit content, after composting, is not further used.

Enterprises are obliged to work out treaties with APA-canal regarding the quantity of water, abstracted for the production process, and about the quantity and quality of wastewater discharged into the municipal sewage system. In order to avoid penalties (for exceeding water pollution thresholds), the enterprises have to use pre-treatment facilities. These facilities are seldom able to treat the wastewater according to the standards. The general economic crisis does not allow enterprises to invest in pre-treatment or in better technology. As a result, a lot of enterprises have been closed down. The majority of the operational enterprises can not comply with water quality standards. They also can not always pay APA-canal for abstraction and discharge and they are not able to pay penalties. To avoid the further weakening of the economy, these enterprises get special time-limited treaties, whereby they get the permission to exceed selected water quality parameter for a certain period of time.

Sludge treatment and disposal is a major problem in the country. The dehydration of sludge from municipal wastewater is carried out on sludge fields. The sludge fields are equipped with a concrete bottom and a drainage system which brings the leaking water back to the plant. However, there were no further investments in treatment plants as well as in sludge fields in the last few years. The fields are overloaded and the content of sludge is not investigated. It is claimed that the sludge is increasingly polluting water and air. In the dry months dust and odour has impact on the people living in the surroundings. In rural areas, the generated sludge is discharged on special areas, not equipped with impermeable bottom layers or drainage networks. Especially severe problems arise in spring after heavy rainfalls, which wash out the sludge and carry it into surface water.

Both, treated and untreated wastewater, is discharged into surface waters. There are no data available about the amount of discharged wastewater. Disinfection after treatment is only carried out in the case of epidemics. Unfortunately, enough chlorine - even for the treatment of drinking water - is mostly not available.

Reuse
The reuse of treated wastewater in any branch of economy is very limited. Although attempts were made to use sludge as fertiliser, sludge use in agriculture is not currently practiced. Untreated wastewater from animal farms was used as fertiliser for crops fed to animals. Today, large animal farms do not exist anymore. Thus, the use of animal waste is limited to small private fields, if transport capacity is available. In 1990, 2'800'000m^3 treated wastewater was used for irrigation. In 1998 it was only 50'000m^3 with a further declining trend.

Legal and regulatory framework
The most important law concerning wastewater is the "Law on payments for environmental pollution" from September 1988, with its part on "Different rates and economic sanctions for the violation of wastewater discharge into the municipal sewage system". Other laws are the "Water Codex" as well as the laws covering protection zones for drinking water abstraction and the protection of the aquatic environment.

Newly elaborated national standards concerning wastewater discharge into water bodies do not exist - still the very stringent water pollution standards of the former Soviet Union are used (see also case study of the Russian Federation section 7.11.1). This results in similar difficulties as reported in section 7.11.1, however difficulties in Moldova are much more pronounced as the economic and financial capacities of Moldova are much more limited than those of Russia.

According to the "Law about local public power", the local authorities have the right to establish for their territory environmental pollution limits. The polluter-pays principle is used for exceeding threshold concentrations. The country is going to introduce uniform rates for wastewater discharge for the population and the industrial sector.

Institutional framework and monitoring
The Ministry of Environment and Territorial Development is the responsible institution for water pollution. Under its auspices, 54 regional State enterprises "APA-canal" are working which are responsible for drinking water supply and wastewater collection/treatment. Furthermore, its 8 regional Ecological Inspections are in charge of wastewater quality control. In addition, the Hygienic-Epidemiological Centres of the Ministry of Health have the right to control and to enforce sanctions against water polluters.

According to the institutional framework of the former Soviet Union, Moldova still has the same structure. That means, that 16 institutions, with its own laboratories are responsible for the use and protection of groundwaters and surface waters. To avoid further duplication and responsibility disagreement, efforts are undertaken to streamline the limited capacities and concentrate on river basin authorities. Monitoring of water resources is carried out by the Ministry of Environment and Territorial Planning, the Hydro-Meteorological Service, the Ecological Inspections, the Hygenic-Epidemiological Centre and others.

Education

The State Technical University of Chisinau is the educational centre for environmental engineering and management. A new section opened recently, namely the UNESCO-Cousteau section with special emphasis on eco-techniques and water engineering. In 1999, a post-graduate study course (1 year) of engineering in the field of wastewater/sanitation and water management was opened. Unfortunately, the access to foreign literature is very limited. There is not much exchange with other research or scientific institutions outside the country, except with Romania. The availability of study material is insufficient. For the operational staff a training centre at the Ministry of Environment and Territorial Development exists which is running in close co-operation with APA-canal.

Public education

"Natura" is a monthly newspaper dealing with environmental matters. The distribution of this paper is limited because of financial difficulties. Especially in the summer period, the papers and the radio announce the proper and safe use of water/wastewater in order to prevent the spread of infectious diseases. In 1997, together with World Bank, a small brochure was published about the use and the protection of drinking water in rural areas. There are several environmental NGO's working, but with limited influence on the broader public. There are some regional environmental centres, financially supported by USAID, which mostly provide services for schools.

Financing

Water consumers, enterprises and households, have to pay APA-canal for heating, water abstraction (drinking water) and wastewater discharge into the network. These fees differ from region to region. In Chisinau, for example, the population pays 1.39 lei/m^3, enterprises pay 7.20lei /m^3 and energy and heating plants 4.25lei/m^3 (1$=5,70lei in January 2000). Any enterprise has to agree with APA-canal on the threshold concentrations of discharged wastewater is in accordance with the national water quality standards. Because of the stringent standards, the enterprise tries to transfer the costs for water pollution to the final product price. Penalties and sanctions which are to be paid for non-compliance are transferred to the ecological fund. The price for exceeding the same water quality parameter varies between river basins (Prut, Dniester) and Chisinau. Enterprises try to avoid paying penalties, which has been possible because of lack of measurement equipment. In spring 2000, 10 measurement facilities will be installed to measure with a frequency of 24 measurements a day. Enterprises which are investing in pre-treatment facilities pay less penalties. However, this is not sufficient to stimulate investments in wastewater treatment as this invest money is not directly tied to improvements in production technology.

Only about 50% of the population is able or willing to pay for water and heating services. The standard amount for the population differs, however the average is about 150l / 24 hours. APA-canal is not able, for the moment, to install water meters. Thus, households have often to pay an average amount of money (independent of the number of persons living in the household). Living on higher floors means to get no water at all, because of a lack of water pressure. The existing water meters are not always exactly calibrated, so the indicated consumption is too high. To buy private water meters is too expensive for most families. Furthermore, frequent water and energy cuts do not encourage the water users to pay the fees to APA-canal.

In rural areas, the population pays for water abstraction from communal wells and for energy. Heating is not centrally provided in rural areas. Penalties for water pollution, compensations etc. feed into the ecological fund, which is also used for reconstruction and investments in the wastewater sector.

The State enterprise APA-Canal Moldova is responsible for financing the collection, discharge and treatment of wastewater. Furthermore, it is responsible for the construction and operation / maintenance of treatment facilities. The State and local budgets are not sufficient to maintain wastewater treatment. Other financial sources to support wastewater treatment are the consumer revenue for water services, national and local ecological funds and foreign credits. Foreign financial aid is limited and mostly used in the capital Chisinau. Thus, for example, a credit by Eurobank for Chisinau is used for the reconstruction of aeration systems in the treatment plant. A loan by the Netherlands is used for the reconstruction of two methane tanks in the wastewater treatment plant of Chisinau.

7.11.4 Wastewater in Chisinau

In the capital Chisinau, about 95% of the population is connected to the sewage system. The other 5% of the population discharges its wastewater into pits, which are cleaned by special slurry-cars and discharged into the municipal sewage system. According to the data of APA-Canal, the length of the sewage system is increasing, (see table 7.19). Newly built houses have to be connected to the sewer system.

In the last decade, not only the amount of discharged municipal wastewater has diminished, but also its concentration (see table 7.18)

Table 7.18: Characteristic of discharged wastewater of the treatment plant in Chisinau (mg/l)

Parameter	1990	1995	1998
BOD5	14	6.6	5.5
Suspended matter	22	9.6	9.2
NO3	5.02	-	2.9
PO4	2.1	-	1.6

The combined sewage network discharges into the only treatment plant in Chisinau which has a capacity of 380'000m^3/24 hours. Here, the wastewater is mechanically and biologically treated. However, there is no N and P removal available. The removal efficiency of the treatment station varies (after mechanical treatment) for suspended matters between 55-60% and for BOD_5 between 20-25%, and is - after biological treatment - about 92%. After treatment the wastewater is discharged into the small river Bijk.

Table 7.19: Sewage network and wastewater discharge in Chisinau

	Unit	1990	1995	1998
Sewage network length	km	594	677	737
Discharge capacity of the treatment plant	1000 m^3/ 24 hours	440	445.2	445.9
Total discharge of the treatment plant*	1000 m^3	135568	124684	120857.7

Note: * All wastewater discharged by the treatment plant is biologically treated.

In Chisinau, as well as in the whole country, the generation of wastewater is still declining, because of the severe economic crisis. From households, the amount of wastewater increased during the last years, whereas it went down in the public sector (administration, schools, kindergartens, etc) and in the industrial sector (table 7.20).

Table 7.20: Share of wastewater generation by sectors in Chisinau (in %)

Sector	1996	1999
Households	74.5	82.6
Public sector (administration, schools, kindergartens, etc.)	15	9.1
Industry	10.3	8.2

The decline in industrial wastewater generation has led to an increase of concentration of hazardous and other substances in industrial wastewater. This is especially true for heavy metals, substances for food conservation, colorants and surface-active synthetic substances. However, the BOD_5 declined at the same time from 157.5 mg/l in 1990 to 103.7 mg/l in 1998. Furthermore, in the last years the industrial wastewater contains unknown or less known substances, which have adverse impact on the treatment process. Because of limited capacity and equipment in laboratories these substances cannot be analysed.

In the mid 1970s, methane was used for heating purposes. As the installations did not comply with air pollution and other technical standards, the project was terminated. Today, with the help of the Netherlands, two of these methane tanks will be reconstructed and will contribute to the energy supply of the treatment plant and the surrounding outskirts. The generated sludge (with 75% of humidity) is transferred to sludge fields. The fields are overloaded and the impermeability of the bottoms is no longer assured. In 1999, 64 t/per 24 hours of sludge were produced and disposed on the already overloaded sludge fields. The BOD_5 of the sludge is about 150 mg/l. In order to get rid of at least some sludge, APA-canal pays already 50% of the transport costs to fields. The amount of reused sludge is minimal.

In 1999, financial resources for investment and reconstruction were jointly provided by APA-canal, the Government and the European Development Bank. Of this,50% of the money will be used for the reconstruction of the drinking water and sewage networks in Chisinau. Another project is going on with the reconstruction of the two available methane tanks in the treatment station in Chisinau. The methane will be used for heating purposes. This project is carried out with the financial support of the Netherlands.

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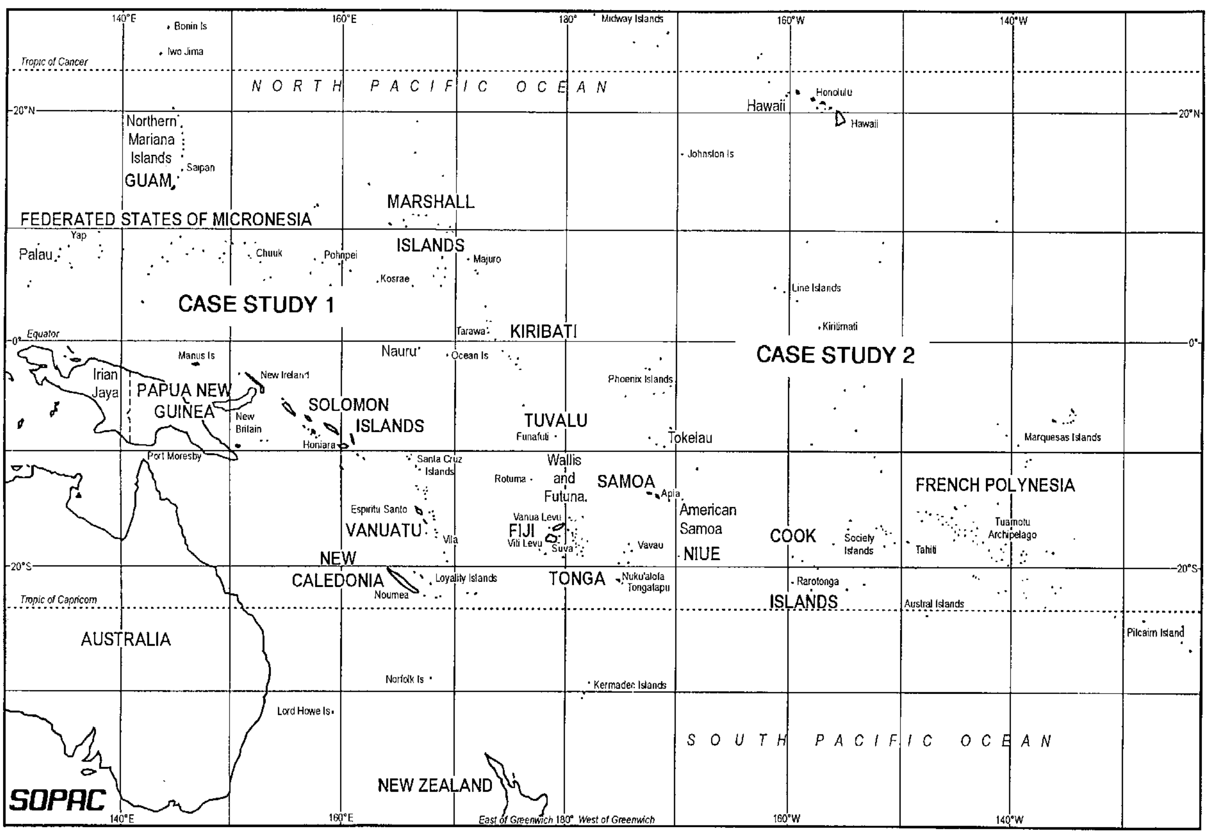
8. Small Island Developing States (Pacific)

8.0 Introduction

8.0.1 Background

The Pacific Ocean covers some 18 million km^2 or about 36% of the Earth's surface. Scattered throughout the Pacific are over 30,000 small islands and a number of larger islands (each over 2000 km^2 in area), which emerge from the sea floor. Of these about 1,000 are inhabited. The Map shows the Pacific Region covered in this report.

Map of the Region & SOPAC Member Countries



Small Island Developing States (SIDS) are unique. They consist of relatively small landmasses completely surrounded by the sea. The ocean isolates SIDS from one another so they have no shared borders with other countries. Travel between islands may be difficult and expensive.

The natural environment throughout the Pacific SIDS is extremely fragile and is highly vulnerable to both natural and human impacts. Natural hazards like cyclones, droughts, earthquakes and tsunamis may strike at anytime and in most places within the Pacific Region. In the past decade, changing climate patterns, rapidly growing populations and increasing pressures on limited natural resources in many countries have produced a crisis of damage to, and depletion of, these resources most necessary for basic life support, especially freshwater supply. The economic and public health implications of the crisis have provoked an urgent need for greatly improved management, planning, operation, and maintenance of the water supply and sanitation sector, associated environmental protection, and conservation of both surface and groundwater resources.

Traditionally and culturally people living on SIDS have strong ties with their coastal marine areas. The disposal of wastewater and stormwater definitely has negative impacts on both freshwater and coastal marine environments affecting public health, ecosystems and the economy of SIDS. Greater efforts and resources are required regionally, nationally and individually to help minimise these impacts of land-based waste disposal on the fragile environment.

8.0.2 Overview compiling method

Information presented in this overview was obtained by:

- Abstraction from existing reports and studies
- Contact with individual agencies responsible for wastewater and stormwater management (see Appendix 1 for responses)
- Personal knowledge of waste disposal methods within the Region

Appendix 1 presents the information collected for this regional overview on a series of data sheets.

While compiling this overview it became obvious that there is a lack of comprehensive and on-going data collection for all wastewater parameters. Very few utilities monitor wastewater influence and / or effluence. Neither is receiving bodies of water (rivers, streams, groundwater or seawater) monitored for quality. Thus there is little hard data available for use in this overview.

The general lack of water sector monitoring and data collection is a major problem in the Region.

8.1 Wastewater characteristics (Topic a)

Unfortunately there is lack of sufficient data available to assess typical characteristics of wastewater produced in the Region. However the following information has been obtained.

8.1.1 Domestic wastewater

The Kinoya wastewater treatment plant in Suva, Fiji, caters for a population of 85,000. Incoming BOD and suspended solids (SS) are approximately 450mg/L and 290mg/L with final effluent at 20-45mg/L and 30-60mg/L respectively. Average dry weather flows are in the order of 270 litres per person per day (l/p/d) while peak wet weather flows are 550 l/p/d.
In American Samoa two primary treatment plants treat domestic sewage only, and have a combined average daily discharge of 8160m^3 with 2600 house and business connections. Average influent for the two plants (in October 1998) shows that BOD and SS were 70mg/L and 50mg/L respectively. Average effluent quality from the two plants, during the same period, was BOD at 30mg/L and SS at 17mg/L. The sewage has been descried as “weak” due to leaking faucets and running toilets. This is reflected in an estimated average flow of 520 l/p/d, which is similar to the peak wet weather flow of the Kinoya treatment plant in Fiji.

No specific information could be found on other wastewater characteristics such as nitrogen and phosphorus concentrations. However a South Pacific Regional Environment Programme

(SPREP) publication *Land-Based Pollutants Inventory for the South Pacific Region*, (see References) has estimated waste loads from domestic wastewater per year that enters the environment as shown in Table 8.1 below. These were based on each country's estimated population, using various methods of treatment and an estimated concentration for each characteristic (ie BOD, SS, N, and P)

8.1.2 Industrial wastewater

Most operators of Regional wastewater treatment plants indicated that industrial wastes were not allowed into their collection systems. It would be naive to think that illegal connections did not exist. Major industries in the Regions include edible oils, sugar refining, fish canning and beer brewing. Most industrial operations provide some sort of treatment and disposal systems, but again there is little information available plus a lack of discharge monitoring. Potential economic opportunities exist with expanding industry growth along with increased industrial waste types and volumes that will have to be dealt with to protect the environment. More control over discharges will need to be exercised by government authorities to minimise adverse effects to the environment.

Table 8.1: Summary for Waste Loads from Domestic Wastewater

Country	Pollutant Constituent (tonnes/yr)			
	BOD	SS	N	P
American Samoa	217.41	259.47	89.48	7.99
Cook Islands	831.02	15.28	53.27	6.46
Fed. States of Micronesia	1,010.93	1,314.26	53.27	6.46
Fiji	3,270.31	1,390.78	2,043.26	240.98
French Polynesia	1,251.51	0.00	812.32	98.46
Guam	2,565.44	1,013.54	781.70	80.27
Kiribati	409.07	406.96	174.57	21.16
Nauru	102.13	160.84	26.54	3.22
New Caledonia	948.27	1,344.30	410.17	49.10
Niue	9.78	0.00	6.35	0.77
North Mariana Islands	99.36	155.07	110.60	6.27
Palau	73.29	73.33	38.63	3.78
Papa New Guinea	5,665.54	2,424.70	3,106.91	374.49
Pitcairn	0.24	0.00	0.61	0.02
Rep. of Marshall Islands	419.05	579.70	150.54	18.11
Solomon Islands	2,136.96	1,762.56	979.15	139.21
Tokelau	12.42	28.80	55.94	0.72
Tonga	563.82	161.62	344.72	43.28
Tuvalu	36.48	16.92	23.00	2.79
Vanuatu	817.74	560.04	457.01	58.35
Wallis and Futuna	64.57	0.00	41.91	5.08
Western Samoa	1,170.04	584.53	739.50	83.04
TOTAL	**21,675.38**	**12,252.70**	**10,499.45**	**1250.01**

Source: SPREP *Land-Based Pollutants Inventory for the South Pacific Region*

Mining activities exist in PNG, New Caledonia, Nauru, Fiji, Solomon Islands and Vanuatu all produce wastewater that requires treatment and are potentially dangerous to the environment. Each mining operation would have its own treatment facilities. The disposal of mining wastewater has not been considered in this report.

The SPREP publication also provides estimated waste loads from industrial wastewater within the Region as shown in Table 8.2.

Table 8.2: Summary Table for Waste Loads from Industrial Wastewater

Country	Pollutant Constituent (tonnes/yr)			
	BOD	SS	N	P
American Samoa	4.53	179.18	255	167.30
Cook Islands	ND	ND	ND	ND
Fed. States of Micronesia	ND	ND	ND	ND
Fiji	510.63	431.92	25.63	0.91
French Polynesia	ND	ND	ND	ND
Guam	ND	ND	ND	ND
Kiribati	ND	ND	ND	ND
Nauru	ND	ND	ND	ND
New Caledonia	37.4	6.1	ND	ND
Niue	ND	ND	ND	ND
North Mariana Islands	ND	ND	ND	ND
Palau	ND	ND	ND	ND
Papa New Guinea	508.94	1,083.40	ND	ND
Pitcairn	ND	ND	ND	ND
Rep. of Marshall Islands	ND	ND	ND	ND
Solomon Islands	513.60	494.81	18.7	0.1
Tokelau	ND	ND	ND	ND
Tonga	ND	ND	ND	ND
Tuvalu	ND	ND	ND	ND
Vanuatu	548.09	241.42	117.21	42.72
Wallis and Futuna	ND	ND	ND	ND
Western Samoa	63.7	10.42	ND	ND
TOTAL	**2186.89**	**2447.25**	**416.54**	**211.03**

Source: SPREP *Land-Based Pollutants Inventory for the South Pacific Region*
Note: ND = No data

8.1.3 Stormwater disposal

There does not appear to be any combined wastewater and stormwater collection systems in the Region. Apart from the larger urban centres in the Region, stormwater collection and disposals systems do not exist. Normally stormwater would follow natural or man-made surface water channels to the sea or just left to seep into the surrounding ground. Stormwater that falls on roofs could be used for domestic water supplies in many SIDS or discharged into the surrounding ground. Potential exists to use stormwater to recharge groundwater aquifers or freshwater lenses that are used for water supply purposes. Instead of directing stormwater to the nearest outlet, the rainwater could be infiltrated into the ground by soakage wells or ponds. Photo 8.1 shows a stormwater disposal well use in Guam.

However, it is expected that some stormwater would enter wastewater sewer systems through old and poorly constructed pipes, and through illegal connections. An example of this would be the difference in the dry (270 l/p/d) and wet (550 l/p/d) weather flows for Fiji's Kinoya treatment plant as noted in section 8.1.1 above.

Photo 8.1: Stormwater disposal well in Guam

8.1.4 Cultural influences

The most drastic influence on wastewater disposal methods would have been that imposed by Western society on the indigenous people by those countries that colonised the Pacific Region. Prior to this intervention I would have imagined that waste disposal was a simple matter managed by families and villages. It was Western society that introduced systems that collected and concentrated large volumes of waste to be discharged at point sources, into the sea or rivers causing pollution of marine and freshwater resources. Many of these systems failed to be sustainable due to lack of resources and local inputs into operation, maintenance and understanding of the systems. (See Case Study 1) Photo 8.2 shows a community toilet in Tarawa, Kiribati that has not been maintained.

Photo 8.2: Community toilet in Tarawa, Kiribati that lacks daily maintenance

8.1.5 Environment and public health

Tables 8.1 and 8.2 indicate the order of pollutants that are discharged into Pacific SIDS environment each year. Approximately 80% of the pollutants enters the coastal marine zone. This very important zone that provides food and recreation for both SIDS residents and tourists is under attack from both land-based and on-the-water pollution. The attributes that attract tourists (sandy beaches, excellent diving and fishing) are being threatened by increasing algal blooms, dying coral and decreasing numbers of marine life. Bathing and eating seafood from polluted coastal waters puts public health at risk as well.

In many atolls freshwater lenses, that have traditionally been used as a source of water, are now being polluted by poor wastewater disposal practices and by increasing population densities of both people and animals. At times people are forced to use polluted water sources thus increasing the risk of poor public health. In many SIDS, local health centres consistently treat a large number of water borne related diseases.

Improved wastewater disposal planning, management and systems would definitely have a positive impact on the environment and improve the general health of SIDS residents.

8.2 Collection and transfer (Topic b)

Approximately 6.1 million people live in the Pacific SIDS of which 3.7 million people (or about 60%) live in Papua New Guinea alone. Of the total population approximately 694,200 (or 11%) are serviced by a reticulated wastewater system. If PNG was excluded from the calculation then approximately 546,000 people out of 2.4 million (or 23%) have access to reticulated wastewater systems. Note that of those people serviced by collection systems (694,200), wastewater from over 100,000 people is discharges direct into the coastal environment without treatment. Also many of the existing treatment plants do not preform as designed. Table 8.3 shows SIDS populations, the number of people served by wastewater reticulation systems and where the effluence is discharged.

The balance (or majority) of the people would dispose their waste through septic tanks, various types of latrines and over water latrines. In some SIDS composting toilets have been introduced as an alternative method of disposal. The bush and beach are still used for defecation, especially by children, in many countries.

It appears that combined wastewater and stormwater collection sewers are not used in the Region. However as mentioned in Section 8.1.3, stormwater does find its way into wastewater systems during periods of rainfall.

There are all types and sizes of pipes used in the Region to reticulate wastewater. Generally it is current practice in the Region to use plastic pipes, however other pipe materials that best suit the situation are used.

In Kiribati, Marshall Islands and Nauru, seawater is used to flush toilets and convey sewage to discharge outfalls. Seawater, used to conserve limited freshwater resources, is pumped to household toilet tanks and collected again for disposal in separate reticulation systems or to septic tanks.

Table 8.3: Estimate of Regional Population and Population Sewered

Country	Population	Population Sewered	Outfall Discharge
American Samoa	35,000	15,500	Ocean
Cook Islands	18,000	None	None
Kosrae, FSM	7,700	1,000	Ocean
Pohnpei, FSM	35,200	14,100*	Ocean
Chuuk, FSM	52,000	9,000*	Ocean
Yap, FSM	11,300	1,100	Ocean
Palau	15,000	5,500	Ocean
Fiji	760,000	110,000	Ocean/River
French Polynesia	196,000	ND	ND
Guam	139,000	151,000***	Ocean
Kiribati	72,000	20,000*	Ocean
Nauru	8,500	3,000*	Ocean
New Caledonia	165,000	92,700	Ocean
Niue	2,500	None	None
Mariana Islands	59,000	39,000	Ocean
Papua New Guinea	3,700,000	138,300**	Ocean/River
Rep. Of Marshall Islands	46,200	28,500*	Ocean
Solomon Islands	333,000	25,000*	Ocean/River
Tokelau	1,200	None	None
Tonga	100,000	None	None
Tuvalu	9,000	None	None
Vanuatu	160,000	None	None
Western Samoa	165,000	None	None
TOTAL	**6,105,600**	**694,200**	

Note: * = Sewered but not treated **=some not treated ***=includes military population
ND = No Data

8.3 Treatment (Topic c)

The Pacific has been described as a “junk yard” of water sector technologies with failed systems spread throughout the Region. Developed country technologies have been superimposed on the Region with less then successful results mainly due to the lack of sustainable resources for on going operation and maintenance. A SOPAC organised Regional workshop on *Appropriate and Affordable Sanitation for Small Islands* was held in Kiribati in 1996. It became clear from the workshop that sanitation involves more than just physical structures for excreta disposal. Health and hygiene education is also regarded as important aspects for any proposed sanitation project. Also community involvement and participation is most important to have a successful project. The production of the SOPAC publication *Guidelines for Selection and Development for Small Islands* (see reference 3) was a result of the Kiribati workshop.

SOPAC has also produced guidelines on Small Scale Wastewater Treatment Plant (see reference 8) that focuses on SIDS. These are further discussed in Section 8.3.1 below.

Previous American influenced countries in the Region (American Samoa, FSM, Guam, Mariana Islands, Marshall Islands and Palau) have some sort of wastewater reticulation system and primary to secondary treatment for their main urban centres. However the standard of effluent produced ranges from raw sewage from Marshall Islands to good quality from Guam and American Samoa. All these countries discharge their wastewater into coastal areas.

Apart from the major urban centres in Fiji, PNG, Kiribati, New Caledonia and the Solomon Islands, plus the above mentioned American influenced countries, the balance of the Region's communities use septic tanks, various types of latrines and over water latrines. Composting toilets have been introduced and trialed in some SIDS including Kiribati, FSM, Fiji and Samoa. (See Case study 2) The bush, beach and the sea are still used for defecation in many places, (Figure 8.1)

Open Defecation

Source: Tearo, 1997

Where there are no latrines people resort to defecation in the open. This may be indiscriminate or in special places for defecation generally accepted by the community, such as defecation fields, rubbish and manure heaps, or under trees. Open defecation encourages flies, which spread faeces-related diseases.In moist ground the larvae of intestinal worms develop, and faeces and larvae may be carried by people and animals. Surface water run-off from places where people have defecated results in water pollution. In view of the health hazards created and the degradation of the environment, open defecation should not be tolerated in villages and other built-up areas. There are better options available that confine excreta in such a way that the cycle of re-infection from excreta-related diseases is broken.

Figure 8.1: Open Defecation

In the Greenpeace Pacific publication, *Sewage Pollution in the Pacific and How to Prevent It,1996* (see references) they state that human excreta is a resource that should be recovered and reused, rather than disposed of into the marine environment. They also state that limited water resources should not be used to convey wastes. They support non-water-carried ecologically engineered treatment systems that use natural processes to convert excrement into usable fertiliser and soil conditioner. Where it is not practical to convert existing conventional treatment systems, Greenpeace recommends that industrial waste and disinfection by chlorination be prohibited in domestic wastewater systems.
Greepeace recommends that the following criteria be used in the selection of technologies for managing human and domestic wastes:

- Achieve zero discharge
- Recover excreta as a resource
- Avoid the use of water
- Prohibit industrial wastes and disinfection with chlorine

In addition significant reductions in pollution discharges from existing conventional treatment systems are recommended by:

- Water conservation
- Use of sludge generated by treatment plants
- Wastewater reuse
- Supplementary treatment using ecologically engineered technologies

Waterless composting toilets meet all Greenpeace criteria. They are being trailed and used in parts of Kiribati, the Federates States of Micronesia, and Fiji indicating good potential.

Composting toilets are best suited for individual households, but are considered to have limited applications in urban conditions.

8.3.1 Small-scale and community technologies

Septic tanks and various types of latrines are exclusively used in the Cook Islands, Niue, Tokelau, Tonga, Tuvalu, Vanuatu and Samoa but are used throughout the Region as well. These methods are mainly for individual family and household use. Some communities (in PNG and Kosrae) use large septic tanks along with some schools and hospitals for wastewater treatment and disposal. Appendix 2 shows various types sanitation systems plus constraints and advantages used in the Region.

UNESCO/SOPAC trials were carried in Tonga to assess what the safe distance between shallow wells and household "toilet" discharges. The study found that most wells used for the study were already polluted. The results were inconclusive suggesting that the minimum distance should be as far apart as possible.

In Yap (FSM) an Imhoff tank is use to treat wastewater. The utility reports that there is a big demand for the dried sludge taken from the Imhoff tank.

Section 8.5.2 discusses land base wastewater disposal in more detail.

Oxidation ponds only appear to be used in Fiji, PNG and Kosrae. Pond treatment methods generally do suit atoll conditions where land is very limited and ground conditions very permeable results in expansive implementation.

There are still circumstances where individual on-site treatment and/or conventional sewage treatment systems may not offer the best solution to deal with shallow groundwater and coastal water pollution problems. Thus guidelines have been developed by SOPAC to use Small Scale Wastewater Treatment Plant (SSWTP) technologies that may be applied where:

- Conventional sewage treatment systems are too expensive.
- Environmental conditions require a higher quality effluent.
- Conventional on-site treatment may have a low community acceptance.
- Low technology solutions, such as the composting toilets, may be inappropriate.

The guidelines give technical criteria for the selection of appropriate wastewater treatment technologies, suggesting a rating scheme to assist in making a choice. For each of the six criteria, there are rating choices of low, moderate and high or a simple yes, no. The procedure is to work through the criteria, rating each, based on the particular circumstances facing the community or group of households. The assessed criteria ratings are then compared to a list of sound technologies that have been evaluated on the same criteria. The likely suitable technologies quickly become apparent. As an example under the criteria of "Electrical Requirement" if no electricity is available the rating given will be no, and then technologies requiring electrical equipment drop out. The various criteria and ratings follows:

- Effluent Quality: (Low, Moderate or High)
  Where health and environmental risks are a major concern, then a better effluent quality may be required. However if the under lying groundwater for example is not considered as a useable resource, then the discharge quality may not need to be of high quality.
- Water Supply: (Yes or No)
  Most SSWTP would require a reliable water supply to convey waste to the treatment plant and to the discharge point. If water were not available then technologies

selections would be fewer. In some cases seawater may be used if freshwater is limited.

- Land Space: (Low, Moderate or High)
  In many SIDS, land is in customary ownership and land use is a very sensitive issue. Some treatment processes require large areas which often is not readily available.
- Maintenance and Operation: (Low, Moderate or High)
  All treatment systems require some degree of maintenance to keep them operating satisfactorily. Many treatment processes require high levels of trained personnel and good supply of spare parts. This is not available in most island applications.
- Cost: (Low, Moderate or High)
  Affordability is often a constraint to providing adequate waste disposal within the Pacific Region. However governments and/or external donors fund many waste disposal schemes. In these cases the users need to be able to pay for the operation and maintenance of the system.
- Electrical Requirement: (Yes or No)
  If no electrical power is available then selection is again limited. Without power this virtually eliminates the use of any pumping to convey, treat and dispose of wastewater. In some cases, low tech turbine or 'water ram' driven pumping systems can still be used.

The following technology rating list should be use as a guide to selecting a suitable technology:

Technology		**Criteria**					
Process Types		**Effluent Quality**	**Water**	**Land**	**O & M**	**Cost**	**Electr-icity**
Primary Treatment							
Composting Toilets	Composting Toilets, Enviroloo, Soltrann II	Low	No	Low	Low	Low	No
Composting Toilets	Composting Toilets, Nature-Loo, Rota-Loo, Biolet	Low	No	Low	Low	Low	Yes
Septic Tank Usage	Septic Tank to disposal field	Low	Yes	Low	Low	Low	No
	Septic Tank with up-flow filter	Moderate	Yes	Low	Low	Moderate	No
	Imhoff Tanks	Low	Yes	Low	Low	Low	No
Septic Tanks	Baffled Septic Tanks	Moderate	Yes	Low	Moderate	Low	No
Ponds/Lagoons/ Tanks	Small Anaerobic Ponds treating domestic wastewater	Low	Yes	Moderate	Low	Moderate	No
	High loaded Anaerobic Ponds with long HRT	Moderate	Yes	Moderate	Low	Moderate	No
	Low loaded Anaerobic Ponds with short HRT	Low	Yes	Moderate	Low	Moderate	No
	Low loaded Anaerobic Ponds with long HRT	High	Yes	Moderate	Low	Moderate	No
	Low loaded Sedimentation Tanks with short HRT	Low	Yes	Moderate	Low	Moderate	No
	Low loaded Sedimentation Tanks with long HRT	High	Yes	Moderate	Low	Moderate	No
Secondary Treatment							
Land Treatment	Slow Rate Process	Moderate	Yes	High	Low	Moderate	No
	Overland Flow Process	Moderate	Yes	High	Low	Moderate	No
	Rapid Infiltration Treatment Process	High	Yes	High	Low	Moderate	No
Ponds/Beds	Reed Bed System (SSF) Subsurface Flow Wetlands/Root Zone TP/Horizontal Gravel Filter	High	Yes	Moderate	Moderate	Moderate	No
	Aerobic Stabilisation Ponds/Oxidation Ponds/Algal Ponds	High	Yes	High	Low	Moderate	No
Filters	Anaerobic Filters	Moderate	Yes	Low	High	High	Yes

Technology		Criteria					
Process Types		Effluent Quality	Water	Land	O & M	Cost	Electr -icity
	Trickling Filters/Percolating Filter	High	Yes	Moderate	Moderate	High	Yes
Activated Sludge	Activated Sludge Treatment	High	Yes	Low	High	High	Yes
Tertiary Treatment							
Hybrid Systems	Hybrid Toilet Systems (T\HTS)	High	No	Low	Moderate	Moderate	Yes
Package Plant Types	N-DN Biofilter Treatment Plants	High	Yes	Low	High	High	Yes
Package Plant Types	Enviroflow Biofilter Treatment Plant Systems	High	Yes	Low	High	High	Yes
Package Plant Types	Cromaglass Unit	High	Yes	Low	High	High	Yes
Package Plant Types	Intermittent Decanted Extended Aeration System (IDEA)	High	Yes	Low	High	High	Yes
	Tertiary Lagoons	High	Yes	High	Low	Moderate	No
	Banks' Clarifiers	High	Yes	High	Low	Moderate	No
	Grass Plots / Wetlands	High	Yes	High	Low	Moderate	No

Source: SOPAC (1999) Small Scale Wastewater Treatment Plant Project Report on Criteria, Guidelines and Technology by Bower and Scholzel.

Note that the "package plants" above are considered tertiary if they are used as a polishing process of treated effluent.
The table ratings were done from the available information. It can be seen from the different ratings that each technology has its strong and weak points and therefore an effective combination of these treatment technologies together would maximise the meeting of the criteria.

8.3.2 Large-scale technologies

Again large treatment plants service the large urban centres such as in Fiji and Guam. Treatment methods include sedimentation, trickling filters, and anaerobic and aerobic lagoons. Currently the Kinoya treatment plant, that service about 85,000 people in the Suva area, is being upgraded using extended aeration and will eventually be able to service 360,000 people. Raw sludge is digested and put into drying beds. The circular digester produces about $63m^3$ of sludge per day. Some of the dried sludge is used as soil conditioner and that not used is dumped into a landfill. In Guam belt presses are used to mechanically dry sludge.

In American Samoa two separate treatment plants use clarigesters for the primary treatment of wastewater. A clarigester is a clarifier that sits on top of a digester constructed as one unit (Figure 8.2). The clarigesters separate settleable solids and floating debris from the inflow of wastewater. Settleable solids sink to the digester compartment where they undergo digestion and eventually removed as sludge. Sludge is removed from the clarigesters and dewatered in covered drying beds. Supernatant from the digester compartment and drainage from the drying beds is pumped back into the plant headworks. Clarigester treated wastewater is than disinfected using chlorine and discharged into two ocean outfalls (30m and 45m deep). As shown in Photo 8.3, the plant also has the facility to except and treat septage, trucked in from septic tanks through the island.

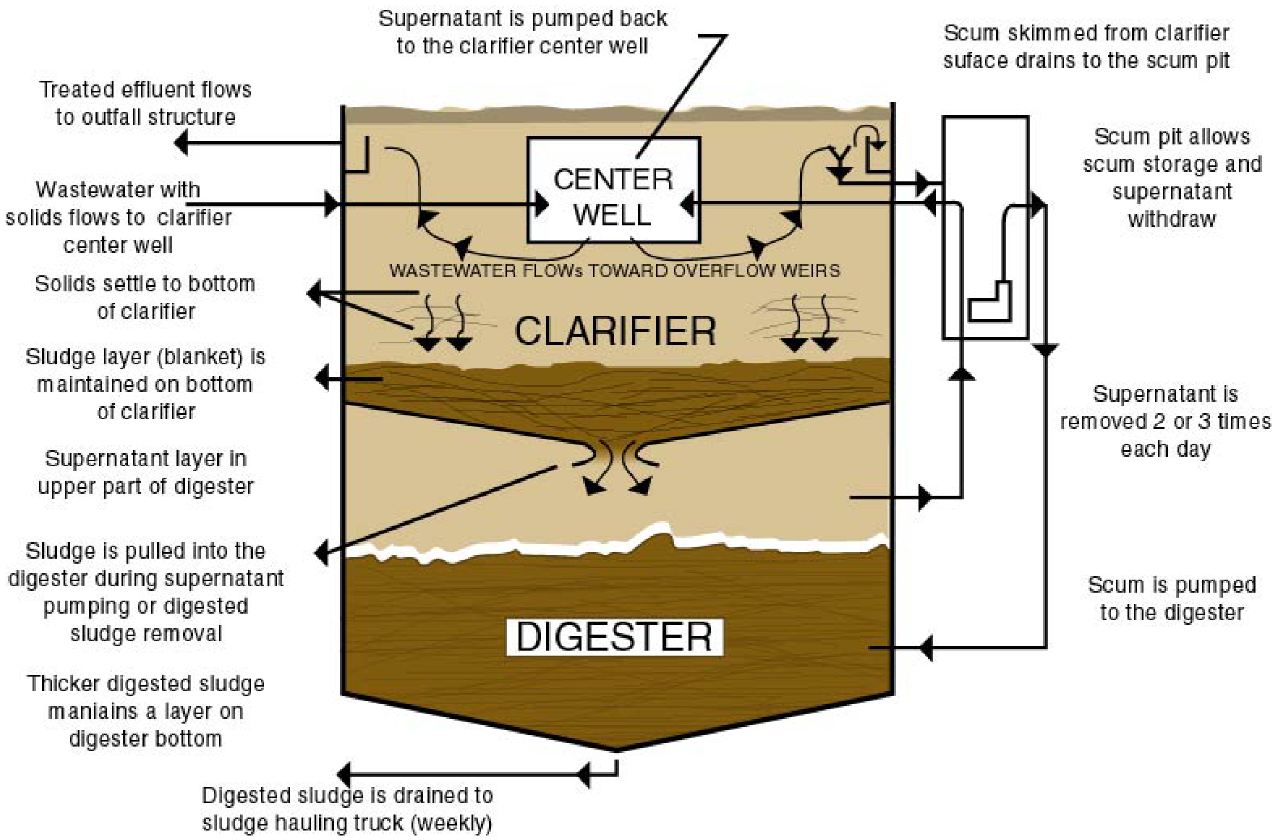


Figure 8.2 Clarigester

Photo 8.3: Disposal of septic tank solids into Clarigester in American Samoa

American Samoa and Guam are the only countries in the Region where treated wastewater is disinfected before discharging into the sea.

It should be noted that raw sewage which has been collected through sewer systems in Kiribati (Tarawa), Nauru, Marshall Islands (Majuro), Solomon Islands (Honiara) and PNG (parts of Port Moresby) is discharge into ocean outfalls with out treatment. Also some of the older treatment plants (Pohnpei and Chuuk) do not operate properly thus not improving influence quality much.

8.3.3 Traditional waste disposal technologies

Before the arrival of missionaries, Western ways and densely populated areas, going to the bush, the beach or the sea was the normal methods to relieve one's self within the Region. Water was not required for flushing, paper was not required and a disposal system was not required. All that was required was a private place and that was not too hard to find. It was the outside world that introduced toilets, collection systems and treatment plants to the Region.

The closest to a Regional "small scale" traditional disposal technology would be the over water (overhung) latrines (also as known as "benjos" in FSM as described in Case Study 1). These are "latrines" that are constructed over a body of water into which excreta drops directly as shown in Figure 8.3. They are cheap and easy to construct no water or paper was required, easy to clean and maintain and some had a great view. Also they were communal in nature (ie several people could use them at same time) and thus presented the opportunity to catch up on the latest gossip. What else could you ask for? However with growing populations resulting in larger discharges and pressure on marine food resources, the risk of pollution and disease also increased. The tourist industry also frowned on them lining the beaches. Over water latrines are now history however that are still use in some parts of the Region.

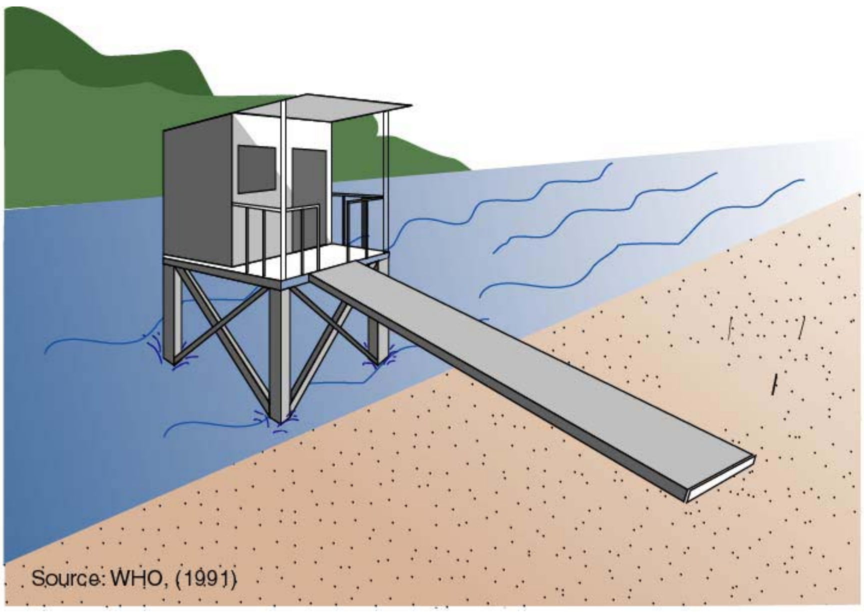


Figure 8.3: Overhung latrines

In rural coastal areas throughout the Region the over water latrine still has potential to provide an important service to the community. Under favourable conditions and good management practices the over water latrines will still be part of the Region's waste disposal seen.

8.3.4 Regional technologies

As seen from above the current wastewater treatment technologies used in the Region range from none to secondary treatment with no one method standing out as the one to use. Without performance monitoring data available, it would still be fair to conclude that many of the existing treatment plants and methods are not working, as they should. The problem may be that the systems are old, expensive to maintain, operate and to replace. The utilities do not have the resources to adequately provide an environmentally friendly service to its customers and the customers cannot afford to pay for an adequate service. Therefore service deteriorates and the environment suffers.

As concluded from the SOPAC workshop on *Appropriate and Affordable Sanitation for Small Islands,* for a sanitation project to be understood, accepted and used, the community must support and be involved with the project's development. Public education and awareness is needed so that the community can see the benefits of both improved health and environment brought about through improved wastewater disposal facilities.

8.4 Reuse (Topic d)

The reuse of wastewater in agriculture and aquaculture has much potential and is used in many other regions. It can replace the use of limited freshwater for the irrigation of crops or be used as an additional source to increase production of crops and in the forestry industry. Aquaculture is becoming popular and may provide additional economic opportunities in developing countries. Nutrients found in wastewater discharges, that normally pollute the environment, are beneficial when used with irrigation and aquaculture applications. However the reuse of wastewater is currently not practiced in the Pacific Region. With many SIDS experiencing limited water resources the reuse of wastewater would be attractive by conserving water and reducing pollution potential to marine and surface water resources.

There is potential in Fiji to use wastewater to irrigate sugarcane and/or for fish farming that has been recently established there. However these rural activities are generally remote from urban centres where treated wastewater is available. SIDS priorities to provide appropriate and affordable sanitation facilities should explore all possibilities to reuse wastewater where ever possible.

In many SIDS and in especially in Papua New Guinea there are strong traditional feelings against the reuse of wastewater. Much talking and convincing would be required to introduce this concept. The issue of 'most appropriate' technology needs to be explored and thoroughly discussed with potential users before proceeding with any new development. Also irrigation is not practice extensively in the Pacific thus water for irrigation use is not a high priority in most SIDS.

It should be noted in Kiribati, Nauru and Majuro saltwater is reticulated to households for toilet flushing to reduce the stress on limited freshwater resources. However the potential to reuse human waste mixed with saltwater would be limited to non irrigation usage.

8.5 Disposal (Topic e)

Table 8.3 notes the Regional SIDS that discharge wastewater through ocean and river outfall systems. (See Photo 8.4 a typical ocean outfall in Honiara) Over water latrines also uses the ocean and rivers to dispose of waste. All countries in the Region use land based disposal systems of various types. With SIDS populations concentrated on coastal areas, much of the land based wastewater discharges would eventually enter the ocean through groundwater and surface water flows. Many coastal areas are being polluted by wastewater disposal resulting in large algae blooms, dying corals (reefs) and the decline in marine life. This all impacts on traditional food resources, public health and the tourism industry. With most SIDS relaying on tourism for economic growth, pristine marine environments are essential to attract tourists and getting them to come back. Thus the promotion of suitable wastewater disposal facilities should be encourage by governments.

Photo 8.4: Typical ocean outfall in Honiara, Solomon Islands

8.5.1 Ocean and river outfalls

Detrimental effects to the environment from areas that are sewered, with various degrees of treatment, can be minimised by using good effluent disposal practices. Locations of ocean outfalls ideally should be beyond the reef, in high circulation areas and below the thermocline. No outfall disposal system in the Region meets all these criteria while a few systems do meet some of the criteria. All too often the outfall locations are chosen by treatment plant or pump station siting opposed to the best outfall locations. These basic design criteria should be investigated for the construction of any new system or the upgrading of an existing system to avoid problems currently experienced by many SIDS. The regional organisation, SOPAC, has both the expertise and equipment to implement outfall location investigations.

The use of wetlands for wastewater is not used much in the Region with only PNG indicating its use. Overseas, wetlands have proved to be an acceptable alterative to discharge of treated wastewater. Wetlands may be either natural or artificial. There is potential in the Region to develop wetlands for the disposal of treated effluent.

8.5.2 Land based

In the Region the Cook Islands, Niue, Samoa, Tonga, Tokelau, Tuvalu and Vanuatu exclusively used land-based disposal of wastewater. Note that groundwater is the main water source for Niue and Tonga hence protection from wastewater pollution is most important. All other countries use this method as well especially in rural areas and on remote islands.

In the urban areas septic tanks are normally use to treat wastewater. If properly designed, constructed and maintained, septic tank systems can treat wastewater adequately. However it is the author's observation that too much effort goes into the sizing and construction of the septic tank itself and very little effort goes into the design and installation of disposal systems for the septic tank effluent. (See Photo 8.5 where septic tank effluent is discharge into unsuitable soils in Suva) In most low island cases the effluent from the septic tanks is discharged into a "soakage" pit giving more or less direct access to the groundwater instead of using the soil as a filter to further improve effluent quality. Infiltration drains may over come this problem but generally are not implemented for digging a soakage pit is less of a task and cheaper then laying a drain. Often when located in urban communities there is insufficient area available to construct adequate effluent disposal systems. In this case the groundwater should not be used for domestic use unless it is treated in some way.

Pollution of groundwater is common in the Region especially on crowded atolls due to ineffective land based disposal methods. On Funafuti, Tuvalu, the groundwater is not used for domestic use due to land based pollution from wastewater disposal. Groundwater reserve areas have been created in Tarawa, Kiribati to protect groundwater lens resources, used for suppling populated areas with water, from pollution. Both Tonga and Niue use the unpopulated areas of the islands to supply freshwater from groundwater lenes. Increasing population growth in the Region is creating pressure on reserve areas to be used for settlement and this may adversely affect the groundwater quality.

With populated areas located on coastal margins, poor land based disposal methods still have impacts on reef and lagoon areas with pollutants being conveyed by groundwater and surface water flows. Hence any improvement to land based treatment and disposal methods would benefit the Regions residents in many ways.

Photo 8.5: Septic tank discharge problem into unsuitable soil conditions

The use of composting toilets, currently being trialed in the Region, has much potential to reduce groundwater pollution, eliminate the need for "flushing" water, and the compost material generated can be use to improve soil conditions. (See case study two) Photo 8.6 shows the construction of a composting toilet in Fiji while Figure 8.4 shown the type of composting toilet used in Kiritimati, Kiribati.

Photo 8.6: Construction of compost toilet in Fiji

8.6 Policy and institutional framework (Topic f)

There is a general lack of effective policy, regulation and institutional structure within the Region's water sector. Also more emphases is placed on providing safe water to households than the disposal of wastewater, and the protection of the environment. Stormwater disposal is given even less attention regarding policy and regulations.

8.6.1 Regulatory framework

In the old American associated SIDS, where wastewater disposal is generally regulated by the Environmental Protection Agencies (EPA) established in each country or state. EPA standards are normally very strict requiring resources that are not available in most SIDS to ensure compliance. This works satisfactorily in Guam and American Samoa. In other countries/states regulations exist, but there are little or no resources allocated to monitor and enforce regulation compliance. Hence the environment continues to suffer at the expense of wastewater disposal.

Health Departments in some SIDS monitor groundwater and surface waters for pollution but again they have little authority and resources to act accordingly. Many countries in the

Region have neither regulations nor standards regarding the discharge of wastes into the environment. Building code standards for septic tank sizing and construction exist throughout the Region, but this do not guarantee an adequate discharge quality. Little attention is given to the disposal of septic tank effluent into the ground, which is a common source of groundwater pollution.

8.6.2 Institutional arrangement

Table 8.4: Agencies Responsible for Wastewater Disposal

Country/State	Wastewater Discharges	Monitoring and Standards
American Samoa	American Samoa Power Authority	EPA monitoring and standards
Cook Islands	Individuals	No monitoring or standards
Kosrae, FSM	Dept. of Transportation & Utility	No monitoring; US EPA standards
Pohnpei, FSM	Pohnpei Utilities Corporation	EAP monitoring and standards
Chuuk, FSM	Chuuk Public Utilities Corporation	EAP monitoring and standards
Yap, FSM	Yap State Public Services Corp	EAP monitoring and standards
Palau	Ministry of Natural Resources & Development	
Fiji	Ministry of Communication, Works and Energy	Ministry of Environment; no standards
Guam	Guam Water Works Authority	EPA monitoring and standards
Kiribati	Public Utilities Board	No monitoring or standards
Nauru	Nauru Phosphate Company	No monitoring or standards
New Caledonia	ND	ND
Niue	Individuals	No monitoring or standards
Mariana Islands	Commonwealth Utilities Corp.	EPA?
Papua New Guinea	The Water Board plus private companies	Royal Commission Standards
Marshall Islands	Majuro Water & Sewer Company	EPA monitoring and standards
Solomon Islands	Solomon Islands Water Board	No monitoring or standards
Tokelau	Individuals	No monitoring or standards
Tonga	Individuals	Health Dept. monitors groundwater
Tvualu	Individuals	No monitoring or standards
Vanuatu	Individuals	
Western Samoa	Samoa Water Board	No monitoring or standards
Schychells	Public Utilities Corporation	Ministry of Environment & Transportation monitor pollution

Individuals = responsible for provide own disposals facilities   ND = No Data

National management of water sector activities within the Region is generally very fragmented with many ministries, government departments, boards, authorities and utilities responsible for an array of activities. Table 8.4 indicates the responsible agencies for the disposal of wastewater for urban areas in the Region. Note that rural areas and outer islands usually come under national health departments for providing assistance in sanitation issues.

8.6.3 Policy framework

Most government polices are general, stating that everyone should have access to safe water and sanitation facilities plus the importance of a healthy environment. However with limited monetary and human resources, most countries relay on bilateral support in the development of national master plans. Often these master plans suggest policy and legislation changes and additions to enable the implementation of sound wastewater disposal practices. Also loaning agencies, like the Asian Development Bank, may put conditions on loans to encourage sustainable sanitation development.

Governments must provide the framework, through policy and legislation, to allow its implementing bodies (ie government departments, utilities, boards or authorities) to be able to operate efficiently. The results would be better disposal systems, healthier people and a cleaner environment. This can be difficult for promoting polices like “user pays”, that would provide the resources to improved wastewater disposal methods and the environment, would be very unpopular with both the public and politicians.

8.7 Training (Topic g)

Regionally there is a lack of adequately trained national personnel within the water sector at all levels. Many utilities still rely on expatriates to plan, operate and maintain water sector systems and project developments.

Most utilities have some sort of in-house training for trades personnel. Treatment plant operators are often trained overseas through both utility and bilateral funding. The American Samoan utility provides training to other American associated SIDS using its own staff. Buddy systems have been established where personnel are exchanged to learn from each other’s utilities. This system has appeared to work well.

Water sector engineers and planners are generally educated overseas on bilateral scholarships. The University of Lae in PNG has a school of engineering and has produced water sector engineers that currently still practice in the Region. However many trained national engineers and planners have left the Region in pursuit of higher compensating employment in New Zealand, Australia and the USA. Hence it is not only training but the retention of trained personnel that has been an on going problem in the Region.

In past years PNG has had the facilities to provide water sector training. However these facilities are now not Regionally utilisation to its potential.

The University of the South Pacific located in Fiji and the University of Guam contributes to the Regions human resources development. Both universities run environment programs but neither have specific water sector engineering programs. Guam University does have a Water & Environment Research Institute.

Often decision makers make discussions that are outside their field of expertise because they are put in position as being the best person available.

Regional organisations like SOPAC, SPREP and SPC have provided water sector training opportunities and short term expertise to the member countries. The Water Resources Unit at SOPAC currently tries to coordinate Regional water sector activities and develop donor funded programs and projects. SPREP also runs programs to assist in waste management. Regional workshop like that ran by SOPAC on *Appropriate and Affordable Sanitation for Small Islands* bring together and expose local practitioners to current sanitation ideas.

The newly formed Pacific Water and Wastewater Association (PWA) potentially will be able to assist with training activities. It gives utilities an opportunity to discuss comment problems that may have been solved by another utility in the Region.

UN originations like UNEP, UNDP, WHO, UNESCO and ESCAP are all potential sources for Regional training opportunities and have already contributed much to human resources development in the Region.

Not only is more and better training required in the Region but better incentives by utilities and governments to retain qualified personnel.

8.8 Public education (Topic h)

Regionally very little effort is put into educating the public about the disposal of wastewater. It's one of those subjects that Pacific residents do not like to hear about and utilities do not like to talk about. Never the less public education and awareness is a very useful tool in promoting good health and hygiene practices as well as the adverse impacts on the environment related to wastewater disposal.

Utilities in Yap (FSM), American Samoa and in PNG have indicated that they undertake public education through awareness campaigns, public meetings, printed materials and the radio. The Solomon Island Water Authority (SIWA) has a very active Public Relations section but its main focus is in providing freshwater to customers.
When trying to introduce a new technology like composting toilets or when promoting new or upgraded projects, the public must be informed to gain their confidence and support.

8.9 Financing (Topic i)

Paying for the collection, treatment and disposal of wastewater is generally expensive in the Region. None of the utilities in the Region even recover their costs in providing a wastewater disposal service. Hence this is a major problem in providing a service that protects public health and is friendly to the environment.

Most utilities in the Region, charge for wastewater services on the basis of the amount of freshwater supplied to each connection. A few utilities do not specifically charge for wastewater services. In all Regional utilities the wastewater services are subsidised by either or their water and electricity charges. Nowhere in the Region does wastewater charges cover the costs of providing the service.

In Fiji and Kosrae (FSM), and maybe other SIDS, respective governments subsidise wastewater disposal. The Nauru Phosphate Company pays for wastewater disposal costs in Nauru.

At least six Pacific SIDS do not have any sanitation services provided, thus there are no charges. Individual households and businesses are responsible for providing and maintaining their own disposal systems in these countries.
In most countries where wastewater systems exist, governments initially were responsible for providing the infrastructure and then turned them over to boards, authorities or companies to run. Generally governments still maintain some control or interest in the utilities especially regarding charging.

Finance for major projects and master plans are still normally channelled through governments to either guarantee loans and/or negotiate bilateral funding. The Asian Development Bank has prepared many Technical Assistance wastewater studies in the Region and has loaned money to implement projects.

8.10 Information sources (j)

The following are contacts for various national, regional and UN agencies that are involved with the water sector in the Pacific Region: (Note that some Indian Ocean SIDS are given as well).

American Samoa Power Authority (ASPA)

P O Box PPB
Pago Pago 96799
American Samoa

Telephone: 684 644 2772
Fax: 684 644 1337/5005
Email: sewer@satala.aspower.com
Contact: Chief Excitative Officer

Topics covered: a, b, c, d, e, f, g, h, i

Description: A public utility that plans, develops and provides electricity, water and wastewater services to the people American Samoa.
Format of information: Report, regulations, polices, guidelines, project funding, public relations
Internet: None
Language: English
Consulting or support services: In house and regional training programs.

Appropriate Technology Enterprises, Inc.

PO Box 607
Chuuk
Federated States of Micronesia

Telephone: 691 330 3000
Fax: 691 330 2633
Email: swinter@mail.fm
Contact: Dr Stephen J Winter
Topics covered: **c, d, e, g, h**
Description: Private consultant who has much practical experience (former Director of WERI in Guam) in small island water issues and may provide information on the water sector within the Federated States on Micronesia.
Format of information: Reports
Internet: NA
Language: English
Consulting or support services: May provide technical advice.

Asian Development Bank (ADB)

P O Box 789
Manila
Phillippines

Telephone: 632 632 6835
Fax: 632 636 2445
Email: NA
Contact: Manager Pacific Region

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Regional development bank that can provide information, technical assistance and finance on the water sector activities for Pacific SIDS
Format of information: Reports,
Internet: www.asiandevbank.org.mainpage.asp
Language: English
Consulting or support services: Regional data collection and technical assistance leading to possible ADB finance of water sector projects.

Caledonienne Des Eaux

15 rue Jean Chalier – P K 4 – BP 812
98845 Noumea Cedex
Nouvelle
Caledonie

Telephone: 687 282 040
Fax: 687 278 128
Email: NA

Contact: Philippe de Greslan

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A public utility that provides water supply services to the people on the New Caledonia.
Format of information: Reports, regulations
Internet: None
Language: French
Consulting or support services: In house training

Central Water Authority

Head Office
St. Paul
Mauritius

Telephone: 230 686 5071
Fax: 230 686 6264
Email: NA
Contact: Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A public utility that provides water and wastewater services to the people on the Mauntius.
Format of information: Reports, regulations, project funding
Internet: http://nub.intnet.mu/mpu/wwa
Language: English
Consulting or support services: In house training

Chuuk Public Utilities Corporation

Box 1507
Wono
Chuuk 96942

Telephone: 691 330 2400
Fax: 691 330 3259
Email: NA
Contact: General Manager

Topics covered: a, b, c, d, e, f, g, h, i

Description: A public utility that plans, develops and provides electricity, water and wastewater services to the people Chuuk.
Format of information: Report, regulations, polices, guidelines
Internet: None
Language: English
Consulting or support services: In house training

Department of Resources & Development

PO Box 12
Palikir
Pohnpei
Federated States of Micronesia

Telephone: 691 3202620
Fax: 691 3205854
Email: NA
Contact: Director

Topics covered: a, b, c, d, e, f, g, h, i

Description: Government department that can provide water sector information for the Federated States of Micronesia
Format of information: Report, regulations, polices, project funding
Internet: None
Language: English
Consulting or support services: Project funding through regional and international organisations

Department of Water Works Ministry or Works, Environment & Physical Planning

P O Box 102
Rarotonga

Telephone: 682 20034
Fax: 682 21134
Email: nbp@oyster.net.ck
Contact: Director

Topics covered: a, b, c, d, e, f, g, h, i

Description: Government department that provide water sector services to the people of Rarotonga.
Format of information: Report, regulations, polices, project funding
Internet: None
Language: English
Consulting or support services: In house training

Guam Environmental Protection Agency - Water Pollution Control Program

Post Office Box 22439
GMF
Barrigada
Guam 96921

Telephone: 671 472 9505
Fax: 671 477 9402
Email: NA
Contact: The Manager

Topics covered: **a, c, e, h, i**

Description: Government agency that regulates, set standards, monitors, collects and enforces water sector performance in Guam.
Format of information: Reports, regulations, standards, guidelines
Internet: NA
Language: English
Consulting or support services: Monitoring of water and wastewater quality standards.

Guam Water Works Authority

P O Box 3010
Agana 96932

Telephone:	671 647 7606/7826
Fax:	671 649 0369
Email:	NA
Contact:	General Manger

Topics covered: a, b, c, d, e, f, g, h, i

Description: A public utility that plans, develops and provides water and wastewater services to the people Guam.

Format of information: Report, regulations, polices, guidelines
Internet: None
Language: English
Consulting or support services: In house training

Majuro Water & Sewer Company

P O Box 1751
Majuro
Marshall Islands 96960

Telephone:	692 625 8934
Fax:	692 625 3837
Email:	NA
Contact:	The Manager

Topics covered: a, b, c, d, e, f, g, h, i

Description: A public utility that plans, develops and provides water and wastewater services to the people Majuro.
Format of information: Report, regulations, polices, project funding
Internet: None
Language: English
Consulting or support services: In house training

Maldives Water & Sanitation Authority

Ameenee Magu,
Machchangolhi
Male 20-04
Republic of Maldives

Telephone:	960 317 568
Fax:	960 317 569
Email:	NA
Contact:	Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A public utility that provides water and wastewater services to the people on the Maldives.

Format of information: Report, regulations, standards, funding
Internet: None
Language: English
Consulting or support services: In house training

Marshall Islands Environmental Protection Authority

PO Box 1322
Majuro
Marshall Islands

Telephone:	692 6253035
Fax:	692 6255202
Email:	NA
Contact:	Mr Abe Hicking

Topics covered: **a, g, h**

Description: Monitor and water quality testing of water supplies in the Marshall Islands
Format of information: Reports, regulations, standards
Internet: None
Language: English
Consulting or support services: Monitoring and water quality analyses

Ministry of Health and Medical Services, Rural Water Supply and Sanitation Section

Ministry and Health and Medical Services
Honiara
Solomon Islands

Telephone:	677 20830
Fax:	677 20085
Email:	NA
Contact:	Mr Robinson Figue

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: This section provides assistance to the rural areas of the Solomons in developing sustainable water, sanitation and health facilities as well as training locals in these areas.
Format of information: Reports, manuals, and guidelines
Internet: None
Language: English
Consulting or support services: Training is all aspects of rural water and waste

Ministry of Natural Resources & Development

Division of Utility, Water & Sewer Branch
P O Box 100
Koror
Palau 96940

Telephone:	680 488 2438
Fax:	680 488 3380

Email: NA
Contact: Chief

Topics covered: **a, b, c, d, e, f, g, h, i**
Description: A public utility that plans, develops and provides water and wastewater services to the people Palau.
Format of information: Reports, regulations, project funding
Internet: None
Language: English
Consulting or support services: In house training.

Ministry of Outer Island Development

Rarotonga
Cook Islands

Telephone: 682 20321
Fax: 682 24321
Email: NA
Contact: Mr Tenga Mana

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A government department that provides a water and sanitation service for the people who live on the outer islands in the Cook Islands.
Format of information: Reports, guidelines, funding
Internet: None
Language: English
Consulting or support services: Provides water sector assistance

Pacific Water Association (PWA)

Naibati House
Goodenough Street
Suva
Fiji

Telephone: 679 306 022
Fax: 679 302 038
Email: Ppa@is.com.fj
Contact: Executive Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Regional organisation consisting of most Pacific water sector utilities plus suppliers, consultants and other interested in promoting safe water supply and wastewater disposal.
Format of information: Reports, guidelines, regional data and information on member utilities.
Internet: www/sopac.org.fj/wru/#PWA
Language: English
Consulting or support services: Provides technical support and training for water sector utilities.

Pohnpei Utilities Corporation

P O Box C
Kolonia
Pohnpei
FSM 96941

Telephone: 691 320 2374
Fax: 691 320 2422
Email: Puc@mail.fm
Contact: General Manager

Topics covered: a, b, c, d, e, f, g, h, i

Description: A public utility that plans, develops and provides electricity, water and wastewater services to the people Pohnpei.
Format of information: Report, regulations, polices, guidelines
Internet: None
Language: English
Consulting or support services: In house training

Public Utilities Board

P O Box 443
Betio
Tarawa
Kiribati

Telephone: 686 262 92
Fax: 686 26106
Email: NA
Contact: Chief Executive Officer

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A public utility that plans, develops and provides electricity, water and wastewater services to the people Kiribati.
Format of information: Report, regulations, polices, guidelines, project funding
Internet: None
Language: English
Consulting or support services: In house and regional training

Public Utilities Corporation (Water & Sewerage Division)

P O Box 34
Unity House, Victoria
Seychelles

Telephone: 248 322 444
Fax: 248 321 020
Email: NA
Contact: General Manager

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A public utility that provides water and wastewater services to the people on the Seychelles Islands

Format of information: Reports, guidelines, regulations
Internet: None
Language: English
Consulting or support services: In house training

Public Works Department

Private Mail Bag
Funafuti
Tuvalu

Telephone:	688 203 00
Fax:	688 203 01
Email:	NA
Contact:	Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Government department that can provide water and wastewater services.
Format of information: Reports, regulations, and guidelines.
Internet: None
Language: English
Consulting or support services: In house training.

Rural Water Supply Department

Private Mail Bag 001
Port Vila
Vanuatu

Telephone:	678 23179
Fax:	678 25639
Email:	NA
Contact:	Mr Roy Matariki

Topics covered: **b, c, e, f, g, h, i**

Description: Government department that assists rural communities with the planning and implementation of water sector services.
Format of information: Reports, guidelines
Internet: None
Language: English
Consulting or support services: Training and public education

Samoa Water Authority

P O Box 245
Apia
Samoa

Telephone:	685 204 09
Fax:	685 212 98
Email:	swalatu@samoa.net
Contact:	General Manager

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A state owned utility that provides water and wastewater services to the people of Samoa.
Format of information: Report, standards, regulations, guidelines, project funding, public relations
Internet: None
Language: English
Consulting or support services: In house and regional training

School of Pure and Applied Science

The University of South Pacific
P O Box 1168
Suva
Fiji

Telephone:	679 313 900
Fax:	679 302 548
Email:	Isalat@usp.ac.fj
Contact:	The Director

Topics covered: **g, h**

Description: Regional educational organisation that can provide water sector information
Format of information:
Internet: www.usp.ac.fj
Language: English
Consulting or support services: Education and training

Solomon Islands Water Authority (SIWA)

P O Box 1407
Honiara
Solomon Islands

Telephone:	677 239 85
Fax:	677 207 23
Email:	Dmakini@welkam.solomon.com.sb
Contact:	General Manager

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A public utility that provides water and wastewater services to the people on the Solomon Islands
Format of information: Reports, regulations, public relations, funding
Internet: None
Language: English
Consulting or support services: In house and regional training

SOPAC Secretariat

Private Mail Bag
GPO Suva
Fiji

Telephone:	679 381377
Fax:	679 370040

Email: alf@SOPAC.org.fj
Contact: Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Regional organisation that can provide water sector information for most Pacific SIDS. A Water Unit exists at SOPCA to provide technical support, guidance, training plus actively seeks donor funding for water sector projects.
Format of information: Reports, guidelines, standards, newsletters, training reports, educational materials
Internet: www.sopac.org.fj
Language: English
Consulting or support services: Has resources to provide water sector support for all member SIDS including data collection, technical services, training and project proposal preparation.

South Pacific Community (SPC)

B P D5 98848
Noumea Cedex
New Caledonia

Telephone: 687 260 000
Fax: 687 263 818
Email:
Contact: Director

Topics covered: **a, b, c, d, e, g, h, i**

Description: A regional organisation that in the past provided sanitation resources for Pacific SIDS. However there are no current sanitation programs in operation.
Format of information: Reports, guidelines
Internet: www.spc,org.fj
Language: English/French
Consulting or support services: Training

South Pacific Regional Environment Programmer (SPREP)

PO Box 240
Apia
Samoa

Telephone: 685 21929
Fax: 685 20231
Email: Sprep@talofa.net
Contact: The Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A regional organisation that has the resources to implement wastewater and environmental programs to enhance the SIDS environment of member countries.
Format of information: Reports, guidelines, and newsletters
Internet: **http://www.sidsnet.org/pacific/sprep/whatsprep_.htm**
Language: English
Consulting or support services: May seek funding and implement programs.

The Water Board

P O Box 2779
Boroko
Port Moresby
Papua New Guinea

Telephone: 675 323 5700
Fax: 675 323 1453
Email: NA
Contact: Managing Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Public utility that provides water and wastewater services to the people of Papua New Guinea.
Format of information: Reports, standards, regulations, funding
Internet: None
Language: English
Consulting or support services: In house and regional training

Tonga Water Board

P O Box 92
Nuku'alofa
Tonga

Telephone: 676 232 99
Fax: 676 235 18
Email: twbhelu@candw.to
Contact: General Manager

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A state owned utility that provides water and wastewater services to the people of Tonga.
Format of information: Reports, regulations, funding
Internet: None
Language: English
Consulting or support services: In house and regional training

UNELCO

B.P. 26
Port Vila
Vanuatu

Telephone: 678 222 11
Fax: 678 250 11

Email: uncelco@uneclo.co.va
Contact: Water Supply Manager

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A private utility that provides water supply services to the people of Port Vila, Vanuatu.
Format of information: Reports, regulations, and standards.
Internet: None
Language: French/English
Consulting or support services: In house training.

United Nations Development Program (UNDP)

Private Mail Bag
Suva
Fiji

Telephone: 679 312500
Fax: 679 301718
Email: webweaver@undp.org.fj
Contact: Resident Representative

Topics covered: **a, b, c, d, e, f, g, h, i**
Description: UN organisation that can provide information on the water sector
Format of information: Reports, and educational materials
Internet: www.undp.org.fj
Language: English
Consulting or support services: Have the resources to arrange water sector country projects.

Water and Energy Research Institute of the Western Pacific (WERI)

UOG Station
Mangilao
Guam

Telephone: 671 7343132
Fax: 671 734-8890
Email: lheitz@uog.edu
Contact: The Director

Topics covered: **a, c, d, e, g, h, i**

Description: Regional educational organisation part of the University of Guam that can provide water sector information.
Format of information: Reports, guidelines, educational materials, newsletters
Internet: http://uog2.uog.edu/weri/index.htm
Language: English
Consulting or support services: Technical and educational assistance

Water and Sewerage Division

C/- Ministry of Communication, Works & Energy
Private Mail Bag
Suva
Fiji

Telephone: 679 384 111
Fax: 679 383 013
Email: NA
Contact: The Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Government department that provides water and wastewater services to the people of Fiji.
Format of information: Report, standards, regulations, guidelines, project funding
Internet: None
Language: English
Consulting or support services: In house and regional training

Water for Survival

PO Box 6208
Wellesley Street
Auckland
New Zealand

Telephone: 64 9 5289759
Fax: 64 9 5289759
Email: johnwfs@clear.net.nz
Contact: Mr John La Roche

Topics covered: **c, d, e, f, g, h, i**

Description: Volunteer organisation that can provide water sector information
Format of information: Reports, newsletters
Internet: None
Language: English
Consulting or support services: May provide information and funding for small projects.

Water Supply and Sanitation, Department of Health

PO Box 807
Waigani
Port Moresby
Papua New Guinea

Telephone: 675 3248698
Fax: 675 3250826
Email: NA
Contact: Mr Joel Kolam

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: Government department that provides sanitation assistance to the rural communities of Papua New Guinea.
Format of information: Reports, guidelines, general data
Internet: None
Language: English

Consulting or support services: Reports, collection on data, guidelines

Water Supply & Sanitation Division, Public Works Department

PO Box 38
Alofi
Niue

Telephone: 683 4297
Fax: 683 4223
Email: waterworks@mail.gov.nu
Contact: The Director

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: A government department that provides water and wastewater services to the people of Niue.
Format of information: Report, standards, regulations, guidelines, project funding
Internet: None
Language: English
Consulting or support services: In house training

World Health Organisation

P O Box 5898
Boroko
N.C.D
Papua New Guinea

Telephone: 675 324 8698
Fax: 675 325 0568
Email: info@who.ch
Contact: Regional Representative

Topics covered: **a, b, c, d, e, f, g, h, i**

Description: UN organisation that may provide resources on public health and how it effects water and wastewater.
Format of information: Reports, standards, and newsletters.
Internet: http://www.oms.ch/aboutwho/
Language: English
Consulting or support services: May provide resources with public health issues.

Yap State Public Service Corporation

P O Box 667
Colonia
Yap 96943

Telephone: 691 350 4427
Fax: 691 350 4518
Email: Robwesterfield@mail.fm
Contact: General Manager

Topics covered: a, b, c, d, e, f, g, h, i

Description: A public utility that plans, develops and provides electricity, water and wastewater services to the people Yap.

Format of information: Report, regulations, polices, guidelines
Internet: None
Language: English
Consulting or support services: In house training

Case studies (Topic k)

The following two case studies demonstrate the use of on-site deposal methods that are most commonly used in the Region as well as composting toilets that are currently being trialed. Both studies were commissioned by SOPAC.

8.11.1 Case Study 1: Sanitation in the Federated States of Micronesia

Introduction

In the 1970's the "benjo" represented the state of the art in sanitary facilities in Micronesia. There were two types: over-water and over-land. The over-water benjo was the most conspicuous and often desecrated an otherwise pristine beach. It consisted of a small enclosure (a privy) with a hole in the floor elevated on poles over the intertidal zone. One would get to this facility by negotiating various types of cat-walks (not always an easy task for the new comer!). At low tide, the mess below these facilities was in plain view. At high tide, one was lucky if it got washed away. The bay in Colonia, Yap, was affectionately called "Benjo Bay" because of the prevalence of these facilities. Similar facilities could be found over rivers (even up-stream of bathing areas) and in mangroves (where there is little or no movement of the water). The over-land benjo was essentially an unimproved pit latrine --- little more than a hole in the ground with a house over it. The user of these benjos would wish he could fly into and out of them and perform his mission without touching anything. In many of the remote atoll islands, there were no toilet facilities at all. The beach or bush were the bath room.

In 1983 a cholera epidemic occurred in Chuuk. Some people say it was a blessing in disguise because it opened people's eyes to the possible consequences of the prevailing sanitary practices. As a result of the epidemic, an effort was made to outlaw benjos of all types and a massive program of building water-sealed toilets in the remote areas was undertaken. Hundreds of them were built such that every household that wanted one could have one. The Chuuk State Rural Sanitation Program by means of aid from the U.S. government provided the materials for the construction of these facilities. In the district centre, a house-sewer connection program was implemented. Although the epidemic was confined to Chuuk, other parts of Micronesia took measures to improve the sanitary facilities on their islands as well.

Today, more than a decade later, it is interesting to observe the state of affairs with respect to toilet facilities throughout Micronesia. To be sure, the classic over-water benjo no longer exists. Has the situation improved? What is the status of all those water-sealed toilets that were installed? Are other types of sanitary facilities being used? This report attempts to answer these and other questions. First, some cultural factors are presented that are relevant to toilet use. Then, three types of toilets are discussed with particular attention being paid to their water requirements, their potential for polluting groundwater, and their cultural acceptability.

Cultural factors

The outer islands of Yap are closely tied to Chuuk culturally and linguistically. Customs (and language, especially) have little to do with Yap proper; the state boundary is a political one. There is a continuum of customs that varies from the most traditional in the outer islands of Yap to the least traditional in the high islands of Chuuk proper. The degree to which the islands follow traditional practices probably varies something like what is indicated below:

<u>most traditional</u>	outer islands of Yap
	Pattiw islands in Chuuk
	Namonweito Atoll in Chuuk
	Pafeng islands in Chuuk
	Mortlock Islands in Chuuk
<u>least traditional</u>	high lagoon islands in Chuuk proper

In a report to the UNDP concerning the design of sanitary facilities for Woleai Atoll in Yap State (Winter, 1991), the writer noted that:

"Three cultural factors exist that must be considered in the design of sanitary and bathing facilities for Woleai. The first is that brothers and sisters and, to a lesser extent, other males and females in the same household can not use the same toilet. Separate male and female toilets must be provided. The second is that water for toilet flushing must be available at the toilet. This is required because defecation is a very personal matter that is never announced verbally or, in the case of flushing a toilet, by carrying a bucket from a distant well to the toilet. If one desires to use a toilet, he simply leaves the group he is in without announcing the purpose of leaving. This especially applies to women in a mixed group. This factor necessitates pumping of groundwater from the source to the toilet facilities (because wells cannot be located adjacent to toilets). A third factor that may be of lesser importance is that men and women's clothing are hung in separate areas after washing. This implies a need for a separate male and female bathing/washing areas".

On the other hand, on the high islands of Chuuk lagoon, it would not be a problem for brothers and sisters to use the same toilet. However, a person (especially a woman) would be embarrassed to be seen carrying a bucket of water in the direction of a toilet. Like so many aspects of island cultures, it is easy for an outsider to make an assumption that is way off base and that will seriously jeopardize the chances of success of a project. Customs vary from island to island. All that can be said is that the person who intends to introduce any change in lifestyle should do his best to first seek out reactions to a proposed project from candid sources. Island people are very polite. Often, rather than give a contrary view, a view that could save a project from failure, people will simply be quiet.

The income level on some of the traditional islands is extremely low. It is certain that some families can not even afford the cost of toilet tissue. This is a consideration that must obviously be factored into any program directed at improving sanitary facilities. A response to this issue is that many water-sealed toilets can tolerate other types of paper. This solves the financial aspect of the problem. All that is needed is a source of paper!

Water-sealed toilets

Like a conventional flush toilet, a water-sealed toilet employs a water trap to seal or confine odours to the sewer pipe or waste storage area. Unlike a conventional toilet, flushing is done manually with a bucket of water. Generally speaking, the types of water-sealed toilets in use in Micronesia are functional but lack the aesthetic qualities of the toilet found in the modern home. However, compared to nothing --- the beach or bush --- they are certainly an improvement.
On the high islands of Chuuk, the water-sealed toilets promoted in the cholera era are gradually disappearing and are not being replaced. Some have been damaged by typhoons. In other cases, the 220 litre drum beneath the toilet has become filled. Many have simply deteriorated with age. According to the former director of the Chuuk Rural Sanitation Program, there is a feeling among the general population that it is the government's responsibility to replace the toilets. Rather than reverting to use of the benjo, people are using the beach and the bush.

On one of the high islands of Chuuk, the writer has observed a new type of benjo --- although its designers probably would not like that designation. It consists of a neat hollow box-like foundation of rock in the intertidal area over which a privy is built. Although the wastes are not exposed to view, the intertidal waters are surely contaminated with them.

Even on Weno, the commercial and governmental centre of Chuuk, it is common at sunrise to see people of all ages, shapes, and sizes taking a walk to the beach or bush in the early morning. The reason is that, even though the area is sewered, toilets might not be functional and/or there is no city water with which to flush them.

On some of the atoll islands of Chuuk there essentially are no toilet facilities. This is at least true in Namonweito Atoll and in the Pattiw area. It is probably true in some other areas as well. Even though water-sealed toilets were installed in these areas following the cholera epidemic, they were quickly abandoned because of the previously described cultural factors.

The writer suspects (but has not confirmed) that the Mortlock Islands in Chuuk State may make more use of water-sealed toilets. Nama Island has fairly well developed rainwater catchment and storage systems, the writer believes, due to the influence of a number of Chuuk State Rural Sanitation Program employees who were (now deceased) from that island. It is probable that they influenced the construction of toilets as well.

In 1990, the writer spent a month on Woleai Atoll, again gathering field data to assist him in the design of appropriate water supply and sanitation facilities. The only toilet on that atoll (5 inhabited islands) was for the UNV stationed on Falalop. This trip resulted in the recommendation of the same toilet design used in Maloelap (Winter, 1991). However, the UNDP did not provide funds for construction of the facilities. That was to be a local effort. The state of affairs in Woleai had not changed in 1992 when a water supply and sanitation survey was made on 13 of the outer islands of Yap State (Seyange, 1992). Aside from the same single toilet on Woleai, only two of the islands in the survey group had toilets. One of these islands had 3 water-sealed toilets, all public; the other supposedly had 70 toilets, 45 of them being public. The writer suspects that public toilets might not be such a good idea owing to the prevailing cultural factors and to the problem of determining who will clean them. However, this opinion is unconfirmed.

The writer recently made a survey of rainwater catchment and storage systems on Pohnpei Island. Although he was not specifically looking for toilet facilities, they did not seem apparent. It may be that in the rural areas of Pohnpei the bush is the prevailing sanitary facility as well.

An often cited objection to water-sealed toilets is that they require water for flushing. This is a valid objection if water from a household's rainwater storage tank is used. However, if groundwater (assumed to be available in unlimited quantities) or seawater is used, it is not. This approach deserves consideration by any community contemplating construction of water-sealed toilets. Unfortunately, toilets are often constructed without first resolving the issue of a source of water for flushing.

Another common objection to water-sealed toilets is that they will pollute the groundwater, especially on atoll islands. This is indeed a valid objection. The writer would strongly suspect that, for example, in the model situation of Mwoakilloa, there is a high level of background contamination of groundwater due to human waste. This situation is probably unavoidable when toilets are sited near to closely spaced homes. Typically, dug wells are in place before the introduction of toilets and, typically, they are also near the home. It is easy to see that, in a populated community, there is a very high probability that groundwater will become contaminated after a program of toilet building. Ten years ago on Chuuk, when there was still a proliferation of water-sealed toilets, the writer recalls that it was frequently difficult to find an acceptable site for a new well because toilets seemed to be everywhere.

There are a few approaches to this problem. One is to only use a well for non-consumptive purposes. Toilet flushing and washing clothes can certainly be done with slightly contaminated water. One can also bathe in it (if he keeps his mouth closed!). However, this is probably an impossible rule to enforce in the case of small children. If one has a large enough rainwater storage tank, it might be possible to use it for bathing except in extremely dry periods. The important point is that, within reason, for some uses it doesn't matter if a well is polluted. In so far as acceptable coliform levels are concerned, a possible guideline might be to require wells used for non-consumptive purposes to have faecal coliform counts that would be acceptable for recreational waters (less than 200 col/100ml).

The problem of groundwater contamination by water-sealed toilets depends on the siting of these facilities. If one is fortunate enough to able to locate a home in a pristine area, it is easy to site wells and toilets properly. This was discussed in the first section of this report.

VIP toilets

The ventilated improved pit latrine has recently been introduced to Chuuk State. The writer is not aware of its use elsewhere in Micronesia. The reason it was introduced is that it requires no water for flushing. Thus, it eliminates the problem of water supply which was often a concern for many of the users of water-sealed toilets. It also has other interesting features.

A VIP toilet is really nothing more than a pit latrine (over-land benjo) with a vent pipe added to the waste area. The logic of the procedure is that air passing over the end of the vent pipe will induce a draft resulting in a flow of air down the toilet and out the vent. When not in use, the toilet seat should be closed. This prevents light from entering the waste area by means of the toilet. If any flies have entered the toilet, they will ultimately try to exit via the vent pipe (flies are attracted to light). If the vent pipe is screened, two of the chief objections to the pit latrine can be eliminated: flies and odour.

During the early 1990's, over 400 of these toilets were installed on the various islands of Chuuk. In general, they have been favourably received. The writer had the opportunity to inspect (use) one of them that was in service. To his surprise, it was indeed odour-free. Sometimes, it is hard to believe that a concept really does work!

The Rural Sanitation Program in Chuuk installed these toilets. According to its former director, the toilets are apt to develop odours in low lying areas. He suspects that this occurs when the groundwater table rises to the level of the wastes in the container. It is noted that this is not a good location for a water-sealed toilet either.

Personal taste is also involved in the selection of a toilet facility. One person that the writer spoke to concerning this type of toilet indicated that some people do not like them because you can see the waste products in the container. This appears to be a matter that could be addressed in public education programs.

An important feature of this toilet is that, if toilet tissue is unavailable, any of the wide variety of alternative traditional materials (that can fit through the opening of the riser!) is acceptable. As indicated in the discussion of cultural factors, this is an important economic consideration for some families.

Although VIP toilets do not involve the addition of significant amounts of contaminated liquids to the groundwater, it would appear that they would still degrade groundwater quality. The first section of this report indicated that research is required to determine acceptable distances between water-sealed toilets and wells. The same questions apply to VIP toilets.

VIP toilets have only been in use in Micronesia for a few years. They are slightly simpler to maintain than water -sealed toilets, do not require water for flushing, and will accept any alternative to tissue that is available. For these reasons they would appear to deserve consideration for application elsewhere.

Composting toilets

A number of composting toilets have been built as demonstration projects in Micronesia (6). At least two have been built in Yap, six in Pohnpei, and one in Kosrae. Other pilot projects may be in progress. Composting toilets have a number of desirable features. Like the VIP toilet, they do not require water for operation. However, in addition, they convert the waste into a resource that can be use as a soil conditioner. Thus, they cause no pollution of groundwater.

The earliest demonstration projects began in 1992. After around two years of operation, the users were happy with the units and report that they are pretty much odour-free.

Some of composting toilet models are commercially available. Others are based on a design developed by Greenpeace (Rapaport, 1995). The intent of the Greenpeace design is that it will be applicable for use in the remote areas of Micronesia. While it does use locally available materials, the construction of it is significantly more complex than a VIP or water-sealed toilet.

The major unanswered question with respect to composting toilets is how users will react to the requirement that the decomposed wastes must be removed from them periodically and spread on the soil somewhere as a conditioner. It may take a great deal of public education to convince people to do this. The long term success of the pilot projects in Micronesia still remains to be demonstrated.

References

Rapaport, D. 1995. Sewage pollution in Pacific island countries and how to prevent it. 39p. Center for Clean Development, Eugene, Oregon.

Rapaport, D. 1995. The Yap head start nonpolluting bathroom. 42p. Center for Clean Development, Eugene, Oregon.

Seyange, K. V. 1992. A field trip report to the outer islands on Yap State.

Winter, S. J. 1991. Water supply and sanitation design study, Woleai Atoll, Yap State, FSM. ATE. v + 46p.

Winter, S. J. 1988. Construction manual for a water-sealed toilet. UNDP. 38p.

Winter, S. J. 1986. Water supply and sanitation facilities for Maloelap Atoll. ATE Tech. Rept. No. 1. vii + 36p.

Winter, S. J. 1988. Operation and maintenance of the Moen water treatment plant chlorination equipment. The development of a VIP toilet for use in the rural areas of Micronesia. ATE. iv + 30p.

8.11.2 Case study 2: Composting Toilet Trial on Kiritimati

Introduction

In June 1995 a trial of composting toilets was initiated and funded on Kiritimati in Kiribati by AusAID, the Australian government aid agency. The trial was conducted by a multi-disciplinary team from the Centre for Environmental Studies at the University of Tasmania in co-operation with I-Kiribati counterparts.

This summary of the 14 month project on Kiritimati will demonstrate the technical, cultural, social and economic issues that are involved in the introduction of composting toilets, and suggest future directions.

Location

Kiritimati (Christmas Island) is a coral atoll in the Line Islands, in the Republic of Kiribati. Kiribati is a small island nation of 33 coral atolls dispersed along the Equator in the Central Pacific. There are three groups of islands and atolls, and Kiritimati is the southernmost atoll in a chain of islands known as the Northern Line. Islands Kiritimati has a highly variable rainfall pattern with an average of about 860 mm per year.

Deterioration in the quality of the ground water has occurred through localised over pumping of the lenses causing 'upconing' of the underlying transition zone and seawater, especially during periods of average or lower rainfall. The ground water is also affected by bacteriological and chemical pollution from human activities. Ground water can be polluted from sources such as domestic animals particularly pigs and dogs, latrines and septic tanks, greywater soaks, fuel storage, agricultural activities, and open rubbish and Babai (taro) pits. The degree and extent of pollution from these sources is not known and would merit extensive study.

The Kiritimati composting toilet trial became part of the Water Supply project that had been planned since 1982, and the recent inclusion of the trial reflected reluctance by the donor government to reticulate contaminated water to the community. It was considered that effective sanitation should be attended to at the same time that the water supply implementation took place. There is a high incidence of enteric disease on Kiritimati and one source of transmission of these diseases is likely to be as a result of faecally contaminated water. The community is encouraged to boil the water before consumption but this does not always happen. Other sources of disease transmission would be through lack of hand washing after defecation, and from flies that come in contact with exposed faecal deposits.

Installation of pre-fabricated imported toilets

In November 1994, 12 toilets were installed in three villages on Kiritimati.

The Wheelibatch toilets were installed in domestic locations on Kiritimati and the two large Cage Batches were installed at the primary schools in two of the villages. One of the smaller Cage Batches was installed at a community clinic that was being funded by the village residents, and the other was installed in a domestic location where the extended family members often numbered more than twenty.

Education/community consultation program

An education program was undertaken to inform the community of the trial and to explain the use and reason for composting toilets. As each culture has different attitudes about sanitation, and each community has different requirements and limitations, ongoing consultation with the residents was a critical aspect of implementation. The development of the education program was based on the advice and assistance of I-Kiribati counterparts, the Community Health Educator and the Assistant Health Inspector.

Introduction of new sanitation technology in any culture is a complex and sensitive process as it affects peoples' lives in the most intimate manner. In Australia, the occasions when composting toilets have failed has been due to a lack of an education component in implementation, or as a result of inadequate pre-sales consultation and after-sales support. In the Kiritimati context, the Australian project team were somewhat handicapped by being unable to speak or understand Kiribati and by being largely unaware of the variety of cultural and political issues that affected the complex social mix on the island.

Installation of locally built toilets

During the reconnaissance visit in June 1994, staff from the Ministry of Line and Phoenix Development which administers island affairs expressed concern that use of the prefabricated toilets would not be sustainable as supply would depend on aid, and maintenance would be difficult due to lack of locally available spare parts and expertise. The Australian project team shared this concern and recommended to AusAID that more toilets be built employing an owner-built design that they had used in Australia for domestic application.

Fortunately, the opportunity arose for the construction of three more toilets because of a decision to extend the trial to non-government housing. Most of the trial participants for the 9 domestic toilets were transient government employers (usually three year terms on Kiritimati), and it was considered necessary to also trial the toilets at non-government houses where people are long term residents and responsible for their own dwellings and leased land. It was thought that the response of these residents would be more likely to reflect that of the normal I-Kiribati villager who owns his or her house-site and has a long term relationship with the land.

The reasons given for installing a local design at that stage of the trial were:

- increased local participation in, and ownership of the project
- increased familiarity with the concept and principles of composting toilets through owner-building
- increased likelihood of sustainable maintenance due to the use of locally available materials
- avoid delay to construction which would be caused by having imported materials shipped from Australia to Kiritimati
- allow a comparison in community response to the pre-fabricated and locally built designs.

The agreement was that the men of each household who were to receive the toilet would be involved in the construction of their own toilet. When the time came for the installations in May 1995, most of these men were working on other building projects and so the construction team was composed of members of the Mayor's family. The Mayor provided invaluable assistance and support during this stage of the project.

As these locally built alternating batch toilet designs are considered the most suitable for small island conditions, details of materials, costing, installation and management recommended in those circumstances follow.

Design features of locally built toilet

The locally built dual chamber batch composting toilets are characterised by the following design features: (See Figures 8.4 & 8.5)

- the toilet base comprises two adjacent chambers which each form a cube with approximately 1m sides, the top of which forms the floor of the toilet building;
- material is deposited through a pedestal or squat plate into one chamber until it is full and then that chamber is closed off to compost and the pedestal or squat plate changed to the alternate side;
- the two chambers each have a floor grate to allow drainage of liquid into a drainage tray below;

- the drainage tray has a 50 mm outlet approximately 25 mm above the base of the tray that allows a standing liquid level, and allows for access in case of blockage;
- the two chambers have hinged doors closing onto a frame which allows for a seal against the entry of flies;
- the chamber doors have mesh covered vent holes which allow the entry of air but offer a seal against the entry of flies;
- each chamber is vented with a vent pipe that extends from the top of the chamber to approximately 1.5 m above the roof of the toilet building;
- the frame of the toilet building is built on top of the two chambers with the stairs and the door on the opposite side of the toilet building to the chamber doors.

Liquid drainage

Evapo-transpiration trench (See Figure 8.5)
The purpose of the evapo-transpiration trench is to ensure that excess liquid that is drained from the toilet does not reach the surface or contaminate the ground water. This is achieved by:

- sizing the trench such that the probability of surcharging is very low;
- planting the top and adjacent areas with species that will maximise evapo-transpirati from the trench.
- bunding and raising the trench to prevent surface run-off into the trench and to maximise rainfall run-off from the top of the trench.

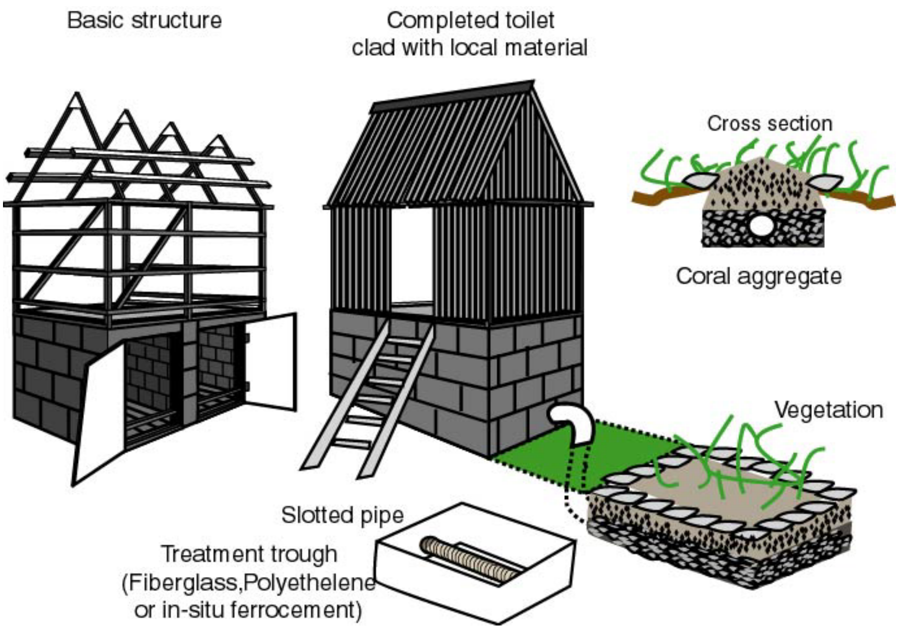


Figure 8.4 Composting toilet used in Kiribati

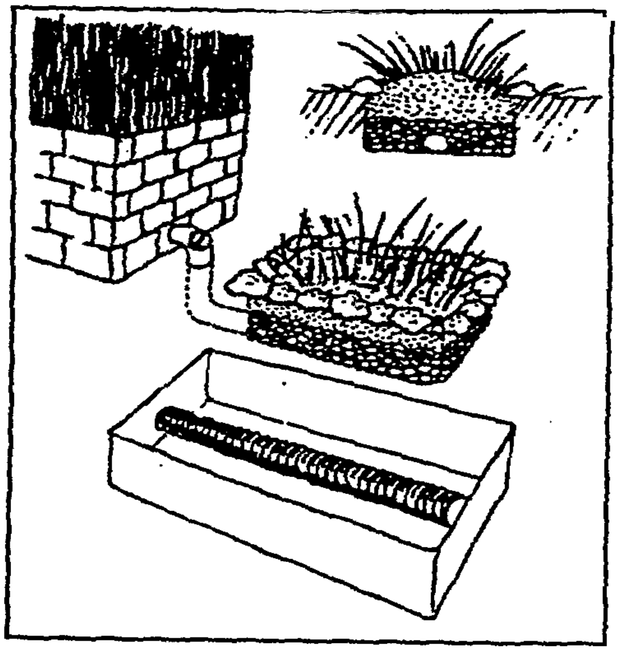


Figure 8.5: Evapo-tranpiration trench

Food crop trees, such as papaya, banana or breadfruit can then be planted adjacent to the trenches to further assist evapo-transpiration. Plants or trees which provide bulking agent could also be planted on trenches.

Costing

The approximate unit cost of the locally built composting toilets on Kiritimati including the toilet building based on the specified design is AUS$2,500 to AUS$3,000. This includes all materials, I-Kiribati labour costs and the liquid drainage trench requirements.

Cultivation

From the results of the education component in the sanitation pilot on Kiritimati, it is recommended that an incentives package be offered to encourage the widespread acceptance and use of the composting toilet on the island and to effect an understanding of the direct relationship between sanitary habits, water quality and hygiene, and the connection with health and nutrition. This package should include a well fenced garden area, seed, trees and plants and gardening assistance and advice. This strategy may not be an effective educational tool in some other cultural context, and community feedback will indicate which strategy is most appropriate in each application. What can be undertaken is, of course, also dependent on available funds and resources.

Results of the trial

The sanitation project was conducted from June 1994 to September 1995, to ascertain whether the composting toilet was appropriate to Kiritimati from a cultural, technical and environmental point of view. An appraisal team of four consultants visited the island to assess the trial in September 1995. The prefabricated toilets had been trialed for ten months and the locally built units were trialed for 3 months prior to the appraisal. The trial project team recommended that this was much too short a trial period to fully cover all the issues involved. However there was considerable pressure to proceed with the long delayed Water Supply project and now that it entailed a sanitation component it was necessary to proceed with the larger Water and Sanitation strategy as soon as possible. A survey was conducted and 258 households out of 316 said they would like a composting toilet. It was decided that the 'pilot' trial had been sufficiently successful to justify an extended trial of some 200-300 composting toilets with the intention that the whole island would eventually be using composting toilets.

Usage

Usage of the prefabricated toilet during the 10 months that the Wheelibatch and Cage Batch toilets were trialed usage slowly increased in the domestic applications. Given the number of people in the households it was obvious from the rate at which the bins filled up that only a percentage of the household were using the toilets in the early stages. The women were more inclined to use the toilets as they offered some privacy. Teenage boys reported that they were embarrassed to be seen entering the toilets. The men preferred to use the bush or the beach. After the video was shown throughout the community, usage increased. Toward the end of the trial some families reported that everyone was using the toilet including the men. The gardening program resulted in a significant increase in the trial participants' interest in the composting toilets.

Usage of locally built toilets was much more consistent from the outset. It appeared from the rapid rate at which the bins filled up that all household members were using the toilet. This may have been due to the more integrated design and it may also have been due to the toilets being within the non-government village and being built by village residents.

At the schools, the usage was consistently low for a number of reasons. The toilet was rather conspicuous and the children were sometimes teased for using it. The teachers insisted on locking the toilet so the children had to ask the head teacher for the key. As many of the children have chronic diarrhoea this would have been a demanding requirement. Most of the teachers did not use the compost toilet but continued to use flush toilets in the teachers nearby houses, which would not have provided very encouraging example to the children. The teachers became more interested in the composting toilet through the gardening program. It is thought that when a greater number of people have composting toilets at home the children will feel less conspicuous using the toilets at school.

Cultural issues

Taboos related to sorcery and faeces were a concern with regard to containing excrement in a bin that may be accessible to prohibited persons. Certain taboos relating to menstruating women using the toilets were also raised. However these issues did not seem to be a problem within the family and as the trial progressed, people became more comfortable using the toilet regardless of these concerns. At the outset of the trial, there was a definite aversion to the prospect of using the end product for fertiliser or any other method of disposal that might allow contact. It was difficult for people to believe that excrement would be transformed into an acceptable material. However when the piles in the toilets did actually produce compost there was a relieved and surprised response, and a marked increase in interest in the toilets. Neighbours to trial participants, who had previously been disinterested or even hostile to the project, requested a composting toilet because they wanted to be able to have a garden and use the compost as a soil improver.

People objected to the height of the buildings. They said they felt uncomfortable using a toilet, which was elevated, above ground. Some said they feared that a person may be underneath. This probably relates to the traditional use of latrines that are suspended over water. The height of the buildings caused embarrassment to some people because they were conspicuous when they climbed the stairs and used the toilet.

A request was made by householders that the toilet doors be made lockable in case strangers used their toilet. However most people lost their keys within a short time and so the toilets then remained unlocked, except for the schools and the clinic.

During the reconnaissance trip in June 1994, the community was asked whether they would prefer squat plates or pedestals for the toilets. Most people replied that they would prefer pedestals but it was indicated that in fact many people would still wish to squat, so a compromise was made by designing a low pedestal which allowed sitting in a semi-squatting position. The pedestal was also made strong enough to support considerable weight for squatting on the seat if desired.

The compost and hygiene

To keep the composting toilet system simple and sustainable it is important that the end product can be disposed of by the users within the house site. Therefore the compost should be free of disease causing organisms. Testing the compost reveals how effective the composting process has been within a particular time frame, and indicates guidelines for usage.

Six of the toilets were ready to be emptied of compost during the September 1995 visit. The compost in each case had the appearance of decomposing bulking agent (whichever leaves or fibre had primarily been added to the toilet during use) and had a pleasant humus odour.

Maintenance

To maintain the composting process, it is preferable that a small handful of bulking agent such as dry leaves or coconut fibre be deposited in the toilet after defecation to allow a suitable mix of material containing nitrogen and carbon. If people forget to add the bulking agent, the pile will eventually smell unpleasant. Usually if a quantity of leaves is then deposited in the toilet, the smell disappears.

As many housewives in Kiritimati sweep up leaves around the house each day and burn them, it was not too difficult for them to collect enough leaves to have a ready supply by the toilet.

When the bin that is being used is full, it is simply a matter of unscrewing the pedestal and changing it over to the side of the empty bin. The toilet can also be designed to have a pedestal or squat plate over each bin so there is no need to make a change. However changing the pedestal and closing the first bin ensures that no one will mistakenly use the bin that is now undergoing a fallow period.

When the fallow period is complete the compost can be shovelled out of the bin and mulched around fenced fruit trees. If the trees are not fenced, pigs and chooks will dig up the compost and scatter it around.

The pedestal rarely requires cleaning as it is low and splayed to avoid material collecting on the inside. If the seat becomes dirty it can be wiped with wet leaves or rags and then these can be dropped into the toilet.

As Kiribati women are responsible for sanitation in the home, all the above chores were conducted by the female head of the family, without any apparent difficulty. Most women reported that it was easier than looking after a water based toilet.

It would be unusual for the drain to become blocked as solid matter is filtered through the false floor at the base of the bin. However, if necessary, the pipe to the trench is approximately half a meter long and could be cleared with a stick through the access point.

Material for repairs to the building frame or the concrete bins would be available on the island. There is little else that requires maintenance in this alternating batch composting toilet design.

Personnel

The introduction of composting toilets requires considerable input from local personnel skilled in a health education and community consultation probably over 2-3 years. A Curriculum Development Officer to work with teachers and students in the schools on water quality and sanitation issues would be most useful at the beginning of the project. For government housing a Sanitation Officer responsible for basic maintenance of toilet structure and on-going advice as to usage of the toilet and the compost would need to be on call in the same way as a plumber would be readily available for attention to waterborne systems. This person should receive remuneration that reflects his or her essential role in the community to counteract any negative association attached to people who take care of toilets. For long term residents in non government housing most maintenance issues could be handled by the householder once they have been exposed to the initial education program, and are in the habit of using the composting toilet.

If composting toilets are initially to be introduced by expatriates it is important to include both female and male team members. Implementation will depend primarily upon the co-operation of the women in the community, and sensitive issues are more effectively discussed between persons of the same gender. Initiating the gardening program should be undertaken by a person with cultural awareness and good people skills in addition to having experience with the hygienic use of human excreta in cultivation, and small plot gardening in physically antagonistic circumstances.

Water Based Sanitation Systems

A centralised sewerage system was installed in Tarawa the capital of Kiribati and some maintenance and pollution problems have been experienced as a result. Pits, aqua privies and septic tank toilet systems have also been installed with the assistance of aid donors and used on Kiritimati for many years. It is often considered to be an indication of status to have a flush toilet in the house. Health education programs have been conducted throughout Kiribati over the last 40 years to deter people from using the traditional location of the bush and the beach for defecation, and to use a water based toilet or pit latrine instead. In some places people have been fined a dollar if they were caught using the beach and their excrement was not immediately removed by the tide. I-Kiribati initially found the water based toilets unacceptable for a variety of reasons but over time and with the persistent efforts of community heath educators the flush toilets have been accepted and increasingly desired by the I-Kiribati. It is therefore a very difficult adjustment to be now told (once again by outsiders) that water borne sanitation systems may be contributing to the high incidence of enteric disease on the island and that a practice that was advocated as a health measure may be a cause of ill health. It is understandable that the composting toilet trial has been viewed with considerable wariness and scepticism, and technology transfer must be conducted with caution, patience and some degree of humility.

In the case of the aqua privy and the septic tank system the effluent from the toilet is discharged directly to the ground water. The septic tank if well maintained provides primary sedimentation but in any circumstances does little to reduce pathogens, BOD or nutrients in the effluent. Berg *et al.* (1976:: 175) suggests that primary sedimentation will not remove viruses at all, and if such effluent is chlorinated will only remove 50% of viruses. If the septic tank is not emptied when necessary then solids will also overflow into the leachfield. The truck used for emptying septic tanks has been out of action for some time on Kiritimati so the residents either allow the tank to overflow or empty the tanks by hand and dispose of the sludge nearby, or in the lagoon. The appropriately sized horizontal trench that can ordinarily provide some treatment of the effluent from septic tank is not used in Kiribati because of the highly porous soil and the inclination to flooding in the rainy season. The leachfield is instead a vertical funnel that facilitates direct drainage to the ground water. As water borne enteric diseases such as Giardiasis are very common on Kiritimati, it is likely that reinfection is maintained partly through contaminated water. However, this has not been empirically proven. Transmission of disease would also be caused through not washing hands after defecation and from flies that come in contact with exposed faecal deposits.

Conclusion

Thorough research and development of mesophilic composting toilets for application in a variety of resource constrained circumstances in the developed and developing world is a relatively recent phenomena. This study is certainly not presented as the final word on the subject. It is hoped that the technical and educational developments that have occurred to date will be expanded upon by those most suited to do so, that is, the individuals and communities that use the toilet, and adapt it to their own needs. Although the composting toilet is strongly recommended as a simple sustainable sewage treatment option it is not the intention of the author to be a technological missionary on this issue.

While advocating due consideration of composting toilets it is not implied that centralised sewerage systems or on-site water borne methods such as septic tanks or pourflush latrines do not have a valid role. It is rather to suggest that in any country, the most appropriate technology should be applied in each location, and that the selection from a range of equally accessible technical options should be based on a thorough appraisal of the cultural, socio-economic and ecological context to be serviced.

NOTE: An Australian funded project constructing composting toilets on Kiritimati is currently being implemented. Thus the suitability of composting toilets on Kiritimati will not be know for another year or two.

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Acronyms

AusAID	Australian Aid
EPA	Environmental Protection Agency
FSM	Federated States of Micronesia
PNG	Papua New Guinea
PWA	Pacific Water Association
SIDS	Small Island Developing Country
SPC	South Pacific Community (formally South Pacific Commission)
SPREP	South Pacific Regional Environmental Programme
SOPAC	South Pacific Applied Geoscience Commission
USP	University of the South Pacific
VIP	Ventilated Improved Pit Latrine
WERI	Water and Environment Research Institute

Appendix 1

Regional Wastewater Agencies Data Sheets

Country/State	Waste Characteristics	Collection and Transfer
American Samoa	8160m$^{3/}$d	2600 house & business connections. AC; PVC & fibreglass pipes pumped systems
Cook Islands	ND	No reticulation system except some hotels
Kosrae, FSM	ND	- oxidation ponds to outfall - septic tanks to outfall
Pohnpei, FSM	2520m^3/d SS~100 mg/l	1120 connections gravity system
Chuuk, FSM	3000m^3/d	- 475 + connection - gravity/pump system - AC/cast iron pipes
Yap, FSM	1600m^3/d domestic	Less than 3000 people pumped system
Fiji	47,000m3/d BOD 450 to 20-44 mg/l SS 290 + 30-60 mg/l	20,700 connections 148,000 people
French Polynesia	ND	ND
Guam	54,000m^3/d total 34,800m^3/d domestic	
Kiribati	BOD 70 to 320 mg/l	- 2,000 connections - pumped raw to outlet saltwater flush
Nauru	ND	Pumped raw to outlets using saltwater flush
New Caledonia	ND	ND
Niue	ND	No reticulation 400 septic tanks
Mariana Islands	ND	ND
Palau	ND	ND
Papa New Guinea	ND	Urban centres only
Marshall Islands	ND	1300 households on Majuro, saltwater flush
Solomon Islands	ND	25,000 people reticulated pumped raw to outfall
Seychelles	2500m^3/day	6% of population has access to reticulation system
Tokelau	ND	No reticulation system
Tonga	ND	No reticulation system
Tuvalu	ND	No reticulation system
Vanuatu	ND	No reticulation system
Western Samoa	ND	No reticulation system

ND = No Data

Country/State	Disposal	Policy & Distortional
American Samoa	Treated effluence discharged into two deep sea outfalls	ASPA utility, EPA standards
Cook Islands	Into ground	Build codes for septic tanks, No standards
Kosrae, FSM	Deep sea outfall (30m), River discharges	Regulations but not enforced
Pohnpei, FSM	Sea outfall	Pohnpei Utility Corp.
Chuuk, FSM	Sea outfall	Chuuk Utility Corp.
Yap, FSM	Sea outfall	Yap State Public Services Corp. EPA but no legislation
Fiji	Sea and river outfalls	Public Works but will be corporatised soon
French Polynesia	ND	ND
Guam	Sea outfall	EPA regulation
Kiribati	3 sea outfalls	Public Utilities Board, No standards
Nauru	5 sea outfalls	Nauru phosphate Corporation
New Caledonia	ND	ND
Niue	Into ground	Building codes for septic tanks, No standards
Mariana Islands	ND	ND
Palau	ND	ND
Papa New Guinea	Sea outfall	The Water Board, Private Companies
Marshall Islands	Sea outfall	Major Water & Sewer Corp. EAP regulations, little enforcement
Solomon Islands	17 sea outfall for Honiara	Solomon Islands Water Authority
Seychelles	Marshes & rivers	Public Utility Corp, Division of Environmental monitors pollution.
Tokelau	Into ground	ND
Tonga	Into ground	Tonga Water Board
Tuvalu	Into ground	Public Work, Building code for septic tanks
Vanuatu	Into ground	ND
Western Samoa	Into ground	Samoa Water Board, No standards

ND = No Data

Country/State	Treatment	Reuse
American Samoa	Primary treatment	None
Cook Islands	Septic tanks & latrines	None
Kosrae, FSM	Oxidation ponds, septic tanks	None
Pohnpei, FSM	Activated sludge but not working	None
Chuuk, FSM	Secondary treatment but not working	None
Yap, FSM	Primary treatment, Imhoff tanks	None
Fiji		None
French Polynesia	ND	ND
Guam	Secondary treatment	ND
Kiribati	None for reticulated, septic tanks & latrines	
Nauru	None for reticulation, septic tanks	None
New Caledonia	ND	ND
Niue	Septic tanks, latrines	None
Mariana Islands	Secondary treatment	ND
Palau	ND	ND
Papa New Guinea	Preliminary, oxidation ponds, septic tanks	None
Marshall Islands	None for reticulation, septic tanks	None
Solomon Islands	None for reticulation, septic tanks and latrines	None
Seychelles		Minimal to gardens
Tokelau	Septic tanks, latrines & over water latrines	None
Tonga	Septic tanks	None
Tuvalu	Septic tanks & latrines	None
Vanuatu	Septic tanks & latrines	None
Western Samoa	Septic tanks & latrines	None

ND = No Data

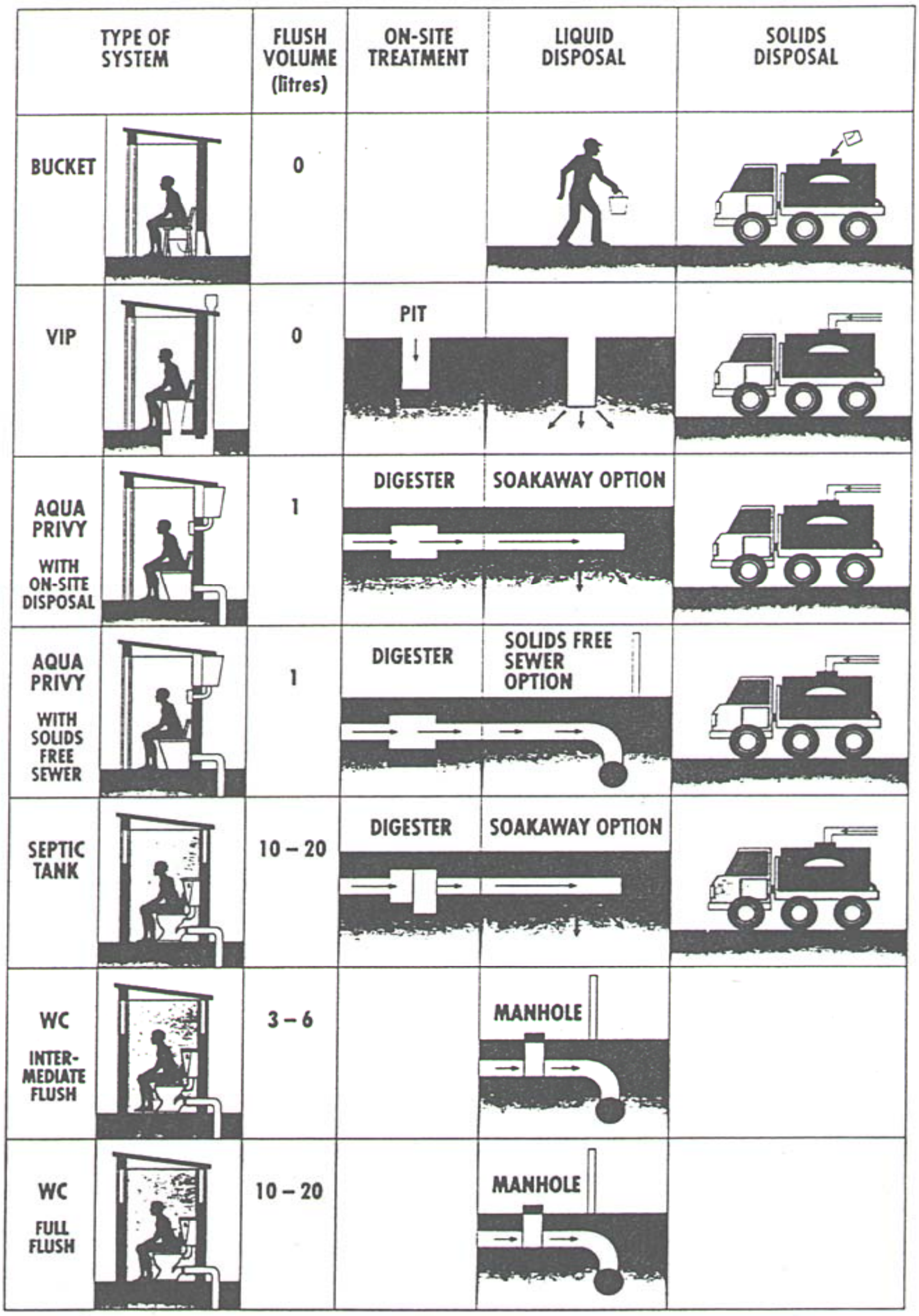
Country/State	Training	Public Education
American Samoa	ASPA privative on state training and regional training	In-house training, buddy system with neighbouring SIDS
Cook Islands	Minimal	None
Kosrae, FSM	Minimal	None
Pohnpei, FSM	In-house training	None
Chuuk, FSM	In-house training	None
Yap, FSM	Local on-going	Yes, radio & public meeting
Fiji	Local & overseas	Minimal
French Polynesia	ND	ND
Guam	ND	ND
Kiribati	Minimal	Minimal
Nauru	In-house	Minimal
New Caledonia	ND	ND
Niue	None	Minimal
Mariana Islands	ND	ND
Palau	ND	ND
Papa New Guinea	In-house & overseas	Public awareness campaigns
Marshall Islands	Minimal	Minimal
Solomon Islands	Minimal	Minimal
Seychelles	ND	ND
Tokelau	None	None
Tonga	Minimal	Minimal
Tuvalu	Minimal	Minimal
Vanuatu	Minimal	None
Western Samoa	Minimal	Minimal

ND = No Data

Country/State	Financing	Stormwater Disposal
American Samoa	Wastewater charged to water bill but still a deficit that is covered by surplus in power sector	Not managed by any agency but Public Water Dept. maintain culverts.
Cook Islands	None	None
Kosrae, FSM	No changed Wastewater budget $US14,000	None Drainage of road areas
Pohnpei, FSM	Through water charges	None
Chuuk, FSM	ND	None
Yap, FSM	No charges, subsided by water/power	Ground soakage, no system, no legation
Fiji	$US0.11/m^3 of water used	Drainage disposal for in urban areas only
French Polynesia		
Guam	ND	Drainage diverted into deep soakage wells
Kiribati	No charges, subsided by water/power	None
Nauru	Paid by Nauru Phosphate Company	Roadside
New Caledonia	ND	ND
Niue	None	Roadside
Mariana Islands	ND	ND
Palau	ND	ND
Papa New Guinea	Based on % of metered water supply	In urban centres only
Marshall Islands	Subsided by water/power	None
Solomon Islands	No charged, subsided by	Honiara by Municipal Authority oversee statements
Seychelles	1/3 of water bill and subsided by water rates	Not allowed into public sewers
Tokelau	None	None
Tonga	None	Roadside
Tuvalu	None	None
Vanuatu	None	Roadside
Western Samoa	None	Roadside

Appendix 2

Regional Wastewater Systems plus Constraints and Advantages



Sanitation system designs (from Palmer Development Group, 1995)

AVAILABLE TECHNOLOGIES

CHOICE	RELATIVE COST	TECHNOLOGY	RISKS	RESOURCE RECLAMATION	PATHOGEN CONTAINMENT	PATHOGEN REMOVAL	CONSTRAINTS	ADVANTAGES
beach/bush	zero	zero	direct F/O transmission	no/yes	no	?	low population good tidal flush (beach) designated defecation site (bush)	easy
night soil	low	very low	F/O transmission at spills social odium vectors/vermin at disposal site	yes	yes	no	requires designated safe disposal good access to houses	easy, private
pit latrines	low-moderate	low	vector breeding	yes/maybe	yes	yes	requires land	private
general	low-moderate	low	pollution potential	yes/maybe	yes	yes	deep soil/water table	low O and M contains pathogens
wet pit	low-moderate	low	groundwater pollution	yes/maybe	yes	yes	requires permeable soils	slow to fill
dry pit	low-moderate	low		yes/maybe	yes	yes		
ventilated	low-moderate	low		yes/maybe	yes	yes	requires exposed site for sunlight and wind	odourless traps vectors
septic tanks general-tank	moderate-high	medium	vector breeding poor construction	yes/maybe	yes	yes	requires water supply requires desludging facility	proven technology
absorption	moderate	low	groundwater pollution	yes/maybe	yes	yes	requires depth of soil/water table	simple
ET	moderate	low	plants may not tolerate	yes/maybe	yes	yes	requires land area	simple
wetlands	moderate-high	medium	overflow, vector breeding	yes/maybe	yes	yes	requires land area	minimal discharge
filters/aeration	high	high	breakdown problems	yes/maybe	yes	yes	expensive	high quality effluent
mix'n match water-borne small sewers	high	medium	pipe-damage pollution households may not connect	maybe	yes	yes	requires pipeline routes requires safe disposal areas	removes wastes
municipal sewers	very high	high	breakdowns	maybe	yes	yes	requires pipeline routes and pumps requires treatment/disposal areas high O and M costs	clean, modern
composting toilet	moderate	medium	very few	yes	yes	yes	requires dry organics requires high set structure	very clean

9. Small Island Developing States (Caribbean)

9.0 Introduction

The Caribbean Region is located to the south of Florida (USA), to the north of South America and bordered by Central American countries to the west. The Region is mainly comprised of "Small Island Developing States" (SIDS). Most of these countries were formerly British and French colonies. They have generally obtained independence, although many are still underdeveloped and are seeking international assistance for development.

The countries/islands within the Caribbean Region include: -
Northern
Cuba, Haiti and Santo Domingo, Puerto Rico, British Virgin Islands, Bahamas Islands, Turks and Caicos islands, Jamaica;
Leeward Islands
Anguilla (UK), St. Kitts-Nevis, Antigua and Barbuda, Montserrat, Guadeloupe, Dominica
Windward Islands
St. Lucia, St. Vincent and the Grenadines, Grenada, Barbados, Martinique
Southern
Trinidad and Tobago

The larger and more developed countries in the region include Cuba, Puerto Rico, Martinique and Guadeloupe, with Jamaica and Trinidad and Tobago leading the way. Countries striving towards development include: Anguilla, Antigua and Barbuda, Bahamas Islands, Barbados, Grenada, British Virgin Islands (BVI) {Tortola being the most populated}, St. Kitts-Nevis, St. Lucia, St. Vincent and the Grenadines, and Turks and Caicos islands. Montserrat is experiencing a decline in development due to recent volcanic problems, where over half of the population has left the island – original population was over 11,000.

Climatically the islands are generally warm, with occasions of unpredictable rainfall. Most of the islands have limestone geology with good drainage and infiltration. Some islands have a hard impermeable to semi-impermeable sub-soil. On some islands clay soil poses problems for stormwater and wastewater absorption.

Despite the slow pace of development, many countries/islands of the Caribbean area are major tourist destinations due to the attractions of the natural environment. There is a real danger that inadequate action and investment into managing wastewater and stormwater will cause harm to the natural environment, eroding ecosystem health and function and associated tourist attractions.

According to Francine Clouden, a sanitary engineer with the Caribbean Environmental Health Institute "…the increased supply of potable water together with the growing standard of living and increased industrialization in the Caribbean, including tourism, has resulted in more and more liquid waste (i.e. wastewater) to be disposed of. Considerable attention is therefore now being paid to liquid wastes in nearly all Caribbean countries. Following from this is the realization that liquid wastes are a major source of land-based pollution of the marine environment and therefore pose a significant threat to the integrity of the fragile ecosystems on whose survival the tourist based economies depend" (Clouden 1999).

In most of the countries of the Caribbean Region there is uneven distribution of inhabitants. "There is a tendency for the population to be concentrated on the coastal belt because of the need to be close to port facilities, fishing grounds and manufacturing and tourism activities.

In Caribbean countries the capital city is the focus of economic and service activity. There are usually a few additional important centres where populations are concentrated. In many instances there is also development in the suburban periphery and continuous linear patterns of settlement, especially along the coast. The remainder of the population is found in towns, villages and tenantries of varying size" (Clouden 1999).

9.1 Wastewater characteristics (Topic a)

Domestic sewage is a significant contributor to marine pollution in the Wider Caribbean Region (WCR), the area shown in figure 9.1 below which includes subregions III and IV containing the majority of countries defined as the Caribbean in this Regional Overview (CEP 1998). The Domestic sewage originates mostly from households, public facilities, and businesses. For wastes from communities where most homes and businesses have piped water, typical pollutant composition of domestic sewage is shown in table 9.1.

Table 9.1: Typical pollutant composition of domestic sewage for WCR

Pollutant	Measurement (mg/L)
Total Suspended Solids (TSS)	200-300
5-day Biochemical Oxidation Demand (BOD)	200-250
Chemical Oxidation Demand (COD)	350-450
Total Nitrogen as N	25-60
Total Phosphorus as P	5-10
Oil and Grease	80-120

Source: CEP Report No. 40 1998, p8.

In unsewered areas, septic tanks are common (CEP 1998). Septic tanks accumulate solids known as septage, which must be removed every few years to ensure effective operation of the system. Typical pollutant composition of septage taken to wastewater treatment facilities is shown in table 9.2.

Table 9.2: Typical pollutant composition of septage taken to wastewater treatment facilities

Pollutant	Measurement (mg/L)
TSS	10,000-25,000
5-day BOD	3,000-5,000
COD	25,000-40,000
Total Nitrogen as N	200-700
Total Phosphorus as P	100-300
Oil and Grease	2500-7500

Source: CEP Report No. 40 1998, p8.

Industrial wastewater has a wide range of pollutant concentrations. According to CEP Report No.40 "…oil refinery wastewater produces 70 percent of the entire BOD load in the Caribbean. These wastes are high in BOD, dissolved salts, odour, phenol, and sulphur compounds. Food processing industries, distilleries, and soft drink industries produce about 5 percent of the BOD load in the Caribbean. They are characterised by very high BOD concentration, suspended solids, dissolved solids, variable pH, and a high level of organic matter. Chemical industries produce about 1 percent of the entire BOD load in the WCR.

Even though they have low BOD strength, wastewater from chemical industries is important because it is frequently toxic to aquatic organisms at very low concentrations. This toxicity may actually mask assessment of BOD for these wastes by killing the BOD test organisms. Pesticides and insecticides used for agriculture are the primary chemical wastes in the Caribbean. These wastes are high in organic matter and are toxic to bacteria and fish" (CEP 1998).

Table 9.3 shows typical pollutant characteristics from common industries in the WCR.

Table 9.3: Typical industrial wastewater pollutant characteristics

Industry	BOD Concentration (mg/L)	TSS Concentration (mg/L)	Oil & Grease Concentration (mg/L)	Metals Present	Volatile Compounds Present	Refractory Organics Concentration (mg/L)
Oil Refinery	100 to 300	100 to 250	200 to 3,000	Arsenic, Iron	Sulphides	Phenols 0 to 270
Tanneries	1000-3000	4000-6000	50-850	Chromium 300-1000	Sulphides Ammonia 100-200	
Bottling Plant	200 to 6,000	0 to 3,500				
Distillery, Molasses, or Sugar Factory	600 to 32,000	200 to 30,000			Ammonia 5 to 400	
Food Processing	100 to 7,000	30 to 7,000				
Paper Factory	250 to 15,000	500 to 100,000		Selenium, Zinc		Phenols 0 to 800
Chemical Plant	500 to 20,000	1,000 to 170,000	0 to 2,000	Arsenic, Barium, Cadmium		Phenols 0 to 5,000

Source: CEP Report No. 40 1998, p9.

Table 9.4 presents a regional summary of pollutant loads for the Wider Caribbean Region. As shown in figure 9.1, the subregions III and IV referred to in table 9.4 represent the Caribbean Region in this Regional Overview. It can be seen from table 9.4 that industrial sources account for as much as 80 percent of the pollution load to the Wider Caribbean Basin (CEP 1998). Even though domestic sources are a relatively small part of the total current pollution load, control of pollution from domestic sources is worthy of considerable attention. This is because pollution control from domestic sources is an important element of public education about environmental and public health issues, and because human health risk arises primarily from domestic sewage.

Table 9.4: Summary Of Pollutant Loadings In The Wider Caribbean Basin In Tonnes Per Year

Parameter	Subregion I	Subregion II	Subregion III	Subregion IV	Subregion V	TOTAL
BOD						
Domestic	115,656	16,785	71,079	4,790	260,171	506,482
Industrial	2,245,762	126,858	357,441	94,707	603,370	3,428,138
TSS						
Domestic	116,327	16,427	90,214	4,617	228,744	456,329
Industrial	27,821,848	149,887	993,964	270,270	2,684,948	31,920,953
TN						
Domestic	34,070	2,419	5,239	710	86,338	128,786
Industrial	17,234	40,526	43,265	37,306	211,107	349,435
TP						
Domestic	19,141	1,467	5,503	531	33,475	60,117
Industrial	17,717	4,519	12,690	15,171	32,537	82,634
Oil & Grease						
Domestic	41,370	2,001	6,089	504	18,975	68,939
Industrial	640,181	8,611	128,024	41,227	162,608	908,701

Source: CEP Report No. 40 1998, p10.

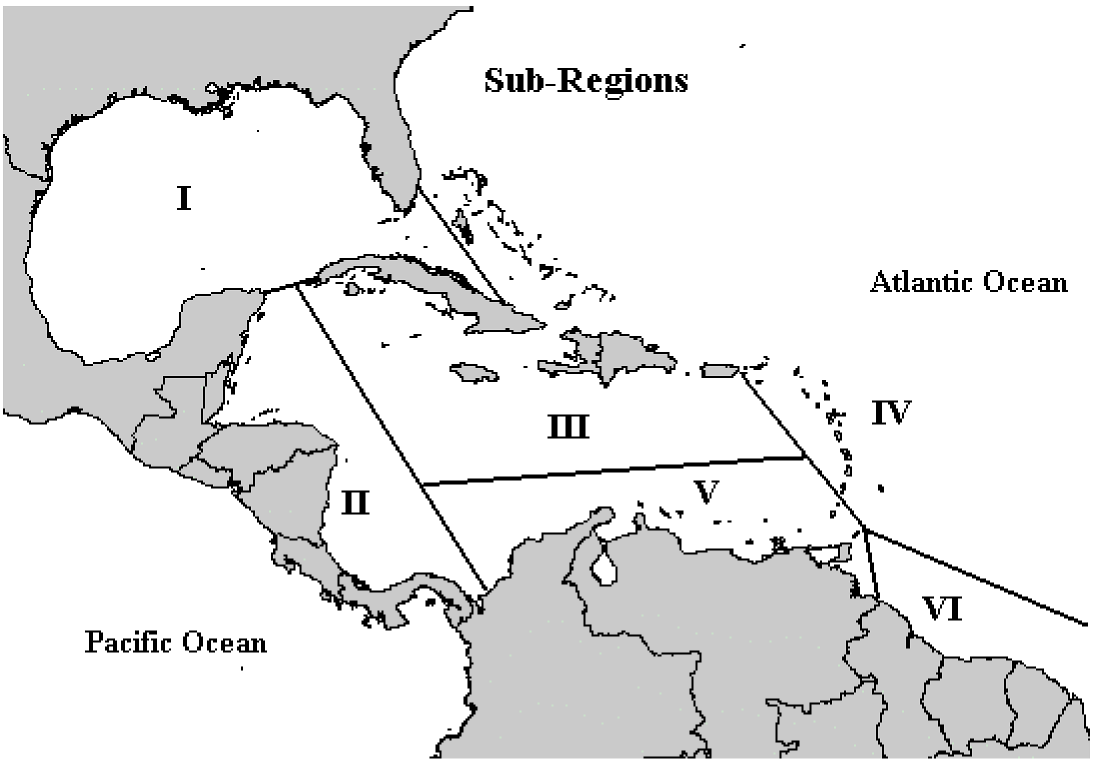


Figure 9.1: Sub-Regions in the Wider Caribbean Region

Source: CEP Report No. 33 1994, Pg.27

9.2 Collection and transfer (Topic b)

Sewer systems do exist in some Caribbean countries (e.g. Barbados, Grenada, Trinidad, St. Lucia). According to Clouden "…in 1991 it was estimated that 10% of the population in the Caribbean is connected to some form of sewer system. Some systems are old, undersized and in need of repair, and many discharge without prior treatment into rivers or the marine environment. New systems are planned in Roseau, Dominica, and the south and west coasts of Barbados. These systems, however, tend to require large capital investments and the planning and implementation stages are very long. There are also numerous small or package plants that are operated by both the public and private sector" (Clouden 1999).

Table 9.5 summarises the degree of collection and treatment in the Caribbean Region. For the most part the degree of collection is poor. Even in places where most of the population is served by collection, as in Trinidad and Tobago, the degree of treatment is very poor resulting in reduced environmental quality of rivers and coastal areas.

Table 9.5: Sewage collection and treatment practices and effects in the WCR

Country	Degree of Collection	Degree of Treatment/ Type of Treatment Prevalent	Problems	Monitoring Programs and Standards
Bahamas	15.6% of population	Deep well injection of raw sewage; 44% of sewage treatment works (STW) are in poor condition or non-operational	High incidence of gastro-enteritis	Department of Environmental Health conducts random sampling of coastal waters; Twice monthly sampling to begin; WHO and U.S. EPA standards currently used
British Virgin Islands	1 collection system	Pumping of raw sewage to marine outfall; some septic tanks	Some wastes return to shoreline, ground water pollution problems	Permanent program being established; monthly sampling of total (TC) and faecal (FC) coliforms in bays. U.S. EPA standard of 200 FC/100 mL and 1000 TC/100 mL
Dominica	13.5% of population	Raw sewage, septage, and effluent disposal into rivers and ocean; virtually non-existent treatment	High incidence of water borne diseases—65 cases typhoid in 1982	
St. Lucia	13.2% of population. Treatment facility in Rodney Bay	Usually untreated raw sewage discharged into ocean & inner harbours; 54% STW are in poor condition or non-operational	High bacterial levels in some coastal areas	Random sampling of coastal waters conducted by the Ministry of Health in co-operation with CEHI
Trinidad & Tobago	Most of population serviced	Lagoons, trickling filters, activated sludge; oxidation ditches; package plants; discharge into estuaries and rivers; 46% in poor condition or non-operational	Poor maintenance practices; high coastal bacterial counts. Rivers of poor water quality.	Institute of Marine Affairs conducts surveys to assess quality of bathing. No legally declared standards yet, but EMA, CEHI, and Trinidad & Tobago Bureau of Standards developing them now.
Montserrat	Virtually none, only 1 STW	Septic tanks with soil absorption fields (volcanic sandy loam provides good treatment)	Inadequate for large developments; otherwise few problems	
Barbados	10% - only for Bridgetown, South Coast system under construction	STW for Bridgetown, outfall for South Coast, remainder of island - septic tanks and soakaway pits or suck wells. Few package plants at hotels.	Nutrients in coastal zone impacting coral reefs. High coliform counts in some coastal areas.	Coastal Zone Management Unit & Environmental Engineering Unit monitor swimming areas for faecal coliform.
Grenada	1 for city of St. George	Virtually no treatment in some areas; about 60% STW in okay condition	Pollution at Grand Anse Bay	

Country	Degree of Collection	Degree of Treatment/ Type of Treatment Prevalent	Problems	Monitoring Programs and Standards
Guadeloupe (France)		Oxidation ponds		Sanitary quality of bathing waters assessed on a regular basis and before each tourist season. Maps issued to describe water quality. EEC guidelines of 1976 used
St. Vincent	6% - only for City of Kingstown	Kingstown has preliminary treatment and outfall. Most of island uses septic tanks and poor quality absorption pits or fields. Few package plants at hotels.	Impervious soils and high water table in coastal zone causes overflowing of absorption fields.	None
Antigua & Barbuda	Mostly for hotels	Numerous hotel package plants; 48% in poor condition or non-operational; septic tank effluent directly to sea		Random sampling by Ministry of Health with CEHI; Emphasis on potable water quality; WHO standards used mainly
St. Kitts - Nevis	Mostly for hotels and hospitals	A few package plants, most in decent condition; the remainder use septic tanks	No serious problems, but some septic tank effluent saturation	Random sampling of coastal waters conducted by the Ministry of Health in co-operation with CEHI
Cuba			Problems concentrated in Havana with faecal coliforms	Ministry of Public Health is in charge of ensuring compliance with standards. Regular monitoring program in place. Standards and guidelines adopted from international organisations & European countries.
Haiti	None	40% population (mostly urban) uses latrines and septic tanks; 41% urban + 12% rural have acceptable disposal means 80-90% septage and latrine solids dumped into rivers and sea illegally	Human waste disposal is most pressing problem	
Jamaica		109 STW; 21 serve Kingston area; however not enough capacity; 8-10 mgd of inadequately treated sewage is discharged into Kingston harbour; 25% STW are in poor condition or are non-operational	Coastal waters are abiotic	There is monitoring of sewage and discharge limits for sewage treatment plants. However, no documentation if regular monitoring of coastal waters is conducted.

Source: CEP Technical Report No. 40, 1998, pg13-15.

9.3 Treatment (Topic c)

Information on treatment is largely derived from CEP Technical Report No. 33 (1994). As stated above initial reports indicated only 10% of the sewage generated in the Central American and Caribbean island countries were properly treated. A more recent survey conducted in eleven CARICOM countries by PAHO reported that the percentage of the population served by sewage systems varied from 2 to 16% (CEP 1994).

The operational conditions of the sewage treatment plants operating in the CARICOM countries have been summarized in table 9.6. The information presented in table 9.6, shows the inadequate number of sewage treatment plants in operation, considering the population of the surveyed countries, together with the poor operating conditions of the available treatment plants. The report also indicates that approximately two thirds of the plants surveyed were poorly maintained in the absence of municipal sewerage systems (CEP 1994).

Table 9.6: Number of sewage treatment facilities (STF) available and operating condition

Country	Population 1990 x 10^3	STF		Operating Conditions %				
		Total	Surveyed					
				G	M	P	NO	?
Antigua & Barbuda	66	20	17	12	35	24	24	5
Bahamas	241	27	18	39	17	22	22	-
Barbados	253	12	12	25	58	17	-	-
Belize	184	3	2	-	50	-	-	50
British Virgin Islands	13	110	10	10	70	20	-	-
Dominica	81	-	-	-	-	-	-	-
Grenada	110	5	5	20	60	20	-	-
Guyana	755	2	2	-	-	50	50	-
Jamaica	2,480	109	28	39	32	21	4	4
Monserrat	13	1	1	-	100	-	-	-
St. Kitts & Nevis	45	4		-	75	25	-	-
St. Lucia	136	17	13	23	23	15	39	-
St. Vincent & the Grenadines	120	1	1	-	-	100	-	-
Trinidad & Tobago	1,320	92	25	12	42	11	35	-
Total	5,817	303	138	25%	36%	22%	13%	4%

Note: G = Good; M= Moderate; P= Poor; NO= Not operational; ?= Undetermined
Source: CEP Technical Report No. 33, 1994, p6.

As stated in CEP Technical Report No. 33, "…very little information exists regarding the number and operating conditions of sewage treatment plants serving coastal communities from most of the rest of the countries of the WCR. In the meantime, the population of coastal dwellers in most of the countries of the regions continues to grow steadily, thus increasing the amounts of poorly treated or untreated sewage wastewaters being discharged into the coastal marine environment. Consequently, the potential for public health problems via primary contact with coastal waters and by consumption of contaminated fish or shellfish is a matter of great concern... Moreover, the discharge of untreated sewage effluents may also produce a long-term adverse impact on the ecology of critical coastal ecosystems in localized areas due to the contribution of nutrients and other pollutants " (CEP 1994).

9.4 Reuse (Topic d)

There appears to be no well documented reuse of wastewater in the Caribbean. The case studies presented at the end of this Regional Overview provide an indication of reuse in the Region. CEP Technical Report No. 33 (1994) infers that 21% of treated wastewater is reused (Section 9.5).

9.5 Disposal (Topic e)

According to Francine Clouden, at the Caribbean Environmental Health Institute, "…the most widely used system of sewage disposal, especially in the urban and peri-urban areas, is the septic tank and soakaway, and in the coral islands like Barbados, the suck well, which is a deep pit to facilitate percolation. In areas where soil conditions do not permit proper infiltration, effluent is generally disposed of in street drains. Many rural communities, especially those without access to piped water supplies, depend upon pit latrines, and the provision of public facilities for wastewater treatment or excreta disposal" (Clouden 1999).

CEP Technical Report No. 33 indicates the following waste disposal practices as an indication for the Caribbean Region: "Re-use of effluent 31 plants (21%); sub-surface discharge, 20 plants (14%); marine disposal, mainly on the shoreline, 42 plants (28%); lagoons and streams, 32 plants (22%); and on site disposal, 21 plants (14%). The above information clearly shows that the disposal practices of discharging mostly untreated wastewater are likely to adversely affect the quality of coastal waters" (CEP 1994, pg6).

9.6 Policy and institutional framework (Topic f)

In the Caribbean Region, the construction/installation of water supply, sewerage facilities and stormwater facilities must be approved by each particular government, as with housing estates, commercial, industrial and agricultural facilities and other infrastructure. The local governments monitor a number of functions in their respective areas and boundaries. This can include the appointment of the number of working personnel, also the monitoring of the quality of facilities and the drafting of actions which must be undertaken by the government.

As outlined in the CEP Technical Report No. 33, most of the countries of the WCR have adopted legal instruments to control the various aspects of domestic and industrial wastewater disposal into the coastal marine environment. Of the 25 countries that undertook the Land Based Sources of Pollution (LBSP) inventory, only nine countries provided relevant documents on legislation on land-based sources of marine pollution. Document UNEP(OCA)/CAR WG.13/INF.12 is a compilation of information on national legislation related to land-based source of marine pollution from the countries of the WCR countries.

The degree to which these legal instruments are applied varies from country to country, and in many cases, the legislation is not enforced. The enforcement of the regulations of these legislation is also hampered by the lack of the necessary infrastructure. Moreover, these regulations tend to be dispersed in general environmental legislation such as fisheries, navigation, etc. There is little doubt that the enforcement of the above regulations may at times conflict with other local interests such as the rapid development and diversification of new industries and resort complexes, particularly in those countries with economies in transition.

Consequently, it is very clear that for many countries of the WCR to meet the obligations of the LBSP Protocol in the future, it will be necessary to seriously consider appropriate strategies to cope with increasing pollution loads affecting their coastal areas.

These strategies will depend mainly on economic factors but also on the political commitment of the different countries of the region to protect the coastal environment" (CEP 1994).

9.7 Training (Topic g)

Very limited opportunities appear to be available for training in wastewater and stormater management in the Caribbean. Opportunities are available in the neighbouring USA and South America.

9.8 Public education (Topic h)

Public education relating to the proper treatment, reuse and disposal of wastewater is more than likely to occur when a decision has been made to install wastewater collection and treatment systems in a particular community. The installation of collection and treatment systems may help to generate interest from the community and any consultation period will help to disseminate information throughout the community.

9.9 Financing (Topic i)

In the Caribbean Region, many countries/Islands are receiving and producing exports and development of agriculture, services, also businesses, with the experience of improved and good livelihood in some of the Regional countries. But in many Regional countries, shortage of funds limits the experience of good livelihood. In the Regional countries, many products are sold to Regional countries, as well as to developed countries. Products exported include sugar, bananas, fruit, vegetables and cotton.

The banana agricultural industry has been supportive to some of the Regional countries by exportation to European countries, Canada and the USA. Some of the Regional Countries which export bananas include Dominica, Grenada, St. Vincent, St. Kitts and Jamaica. The export of sugar to the USA and European countries is generally from Barbados, St. Kitts and other regional countries.

But the major provision of finance in the Region is by "Tourism", which is due to the excellent existence of coastal areas, with good clean beaches for sea-bathing, diving to view marine ecosystems (coral reefs sea-grasses, fisheries), also the availability of boats for sailing and also viewing the sea and sea-bed ecosystems. Tourism contributes major income to Caribbean Regional countries, which include Barbados, Antigua, Jamaica, St. Lucia, Grenada, Tortola and St. Kitts. But to sustain the attractiveness of the countries/Islands, there needs to be the consistence of a high standard of environmental conditions. In coastal areas, marine and inland areas, with the protection of health there must be good quality water supply, also good management and operation of wastewater and stormwater, also the control and disposal of garbage.

As a result of the need for environmental improvement in some areas and Islands, financial assistance generally sought form international agencies, which include the Inter-American Development Bank (IADB), World Bank, PAHO, USAID and UNEP. Trinidad is one of the Regional countries requiring lesser financial assistance, as the country has the largest "oil production" in the Region from which finance is obtained by export of oil and petrol. The British Virgin Islands (mainly Tortola and Virgin Gorda) and Turks and Caicos Islands receive financial assistance from the British Government. To assist with maintaining the high quality of health and environmental conditions, projects which are being financially assisted by International agencies and developed countries by loans and gifts in some Regional Countries/Islands include:-

a) The reconstruction of the Roseau Sewerage System in Dominica. There will be a sewage treatment plant at Baytown on the West, with a marine outfall 1000 feet (330 m) offshore, with the reported cost over US$13 million.

b) In Barbados, after construction of Bridgetown sewerage system, there is currently the construction of the south coast sewerage system: The IADB estimate of the project is US$25.4 million, but it is expected to cost over US$30 million.

c) There are also designs and plans for sewerage projects in Grenada and St. Vincent.

   (i) In Grenada the estimated cost of the projects are US$15 million which will include the extension of the St. George's sewerage system, construction in the St. John's area, and a sewerage system in Grenville.

   (ii) In St. Vincent, there is a planned extension of the Kingstown sewerage system, also a new sewerage system on the south coast. The estimated cost of the sewers is EC$22 million. The three (3) pumping stations and marine outfalls are estimated to cost EC$14 million.

d) In St. Lucia and Grenada there is need for sewage treatment plants, and there is also need to determine the location and lengths of outfall by oceanographic studies;

e) In Anguilla there is need for a sewerage system in the capital "The Valley". There is need to restrict pollution of groundwater in the flat terrain of the Island;

f) In St. John's, the capital of Antigua, there is need for a sewerage system to reduce pollution of the Harbour and adjacent marine areas. The soil in the town is clay with no absorption of effluents. There is also need to improve the capacity of drains, also to statutorily impose restriction of disposing wastes in drains.

Finance is needed for connections, reconstruction, and in some cases improvement of wastewater and stormwater facilities for environmental and Public health improvement.

9.9.1 Government investments

According to CEP Technical Report No.33 (1994) a good example of this approach is the work that is being carried out in Cuba to reduce the impact of pollution loads affecting sensitive coastal areas. In this regard, the following actions are being undertaken:

a) reduction of the oil and grease pollution loads affecting the waters of Havana Bay. In order to achieve this goal the Government of Cuba established a programme to control point and non-point sources.

   The non-point sources were related to the discharge of used oil from automobiles. This oil is collected from gas stations for reprocessing. Originally, these oil was continuously discharged into the sewage system, thus polluting the waters of the Bay.

   Concerning the control of point-sources of oil pollution, investments were made to reduce the loads originating from the oil refinery and the gas plant. This caused in the oil pollution in Havana Bay to be reduced by 50%.

b) At the national level, the Government is enforcing strict comprehensive regulations for the establishment of new industries along coastal areas based on environmental impact assessments.

c) 2000 oxidation ponds and lagoons were constructed for the treatment of domestic wastes from small communities and organic wastes from food processing plants and paper mills. Previously, the above wastes were discharged into rivers, some of them reaching coastal areas.

d) Under the same programme, effluents and residues from 157 sugar refineries are being utilized for the irrigation of sugarcane fields and as fertilizers.

e) Finally, feed load residues are being utilized for soil improvement and energy production.

9.9.2 International financial assistance

To remedy some of the most pressing pollution control problems some countries (especially island countries) have resorted to international assistance, for example through the International Development Bank (IDB).

The Government of Barbados negotiated with the IDB a loan to improve the sewerage system in the city of Bridgetown (35,000 inhabitants). That project was completed in 1982. The project included the appropriate collection of sewage wastewaters and pumping systems, the construction of a secondary sewage treatment plant and marine outfall 300 meters long. The project was financed through the loan from IDB for US$ 29 million with a contribution of US$ 2.7 million from the Government of Barbados.

A second loan was recently obtained to treat sewage wastewater generated by hotels and the local population along the southern coast of Barbados. The project includes a collector, a primary sewage treatment plant and the construction of a marine outfall 1.1 km. long. This project will be financed through a loan from the IDB for US$ 51 million and from the European Investment Bank (EIB) for US$ 11 million with a contribution of 11 million from the Government of Barbados.

In the case of Costa Rica a project for the rehabilitation of the sewerage system of the city of Limón, that was destroyed by an earthquake in April 1991, has being negotiated with the IDB for a loan of US$ 5 million. At this point it will be necessary for the Government of Costa Rica to negotiate an additional loan to build an outfall to discharge primary treated wastewaters into the coastal environment.

Trinidad and Tobago successfully negotiated an IDB loan for the improvement of an oil refinery located at Point-à-Pierre on the west coast of Trinidad. The purpose of the project is to strengthen the capacity of Trinidad and Tobago to exploit the oil and gas of resources by boosting the capacity of the old oil refinery at Point-à-Pierre. This will allow the refinery to produce products of high market value and to enhance oil recovery in the production field.

The project financed by the IDB will cost US$ 36 million and has three components:

(i) secondary recovery project;
(ii) waterflood project; and

(iii) refinery up-grade.

The execution of these components will assist in reducing land-based sources of oil pollution, such as "produced waters", treatment facilities, sulphur recovery unit, etc.

9.9.3 Service and pollution taxes

There are clear advantages in developing financially self-sufficient systems to control pollution loads from land-based sources, for example, in the Netherlands Antilles (Curaçao, Bonaire, Saba, St. Eustatious and St. Maarteen) a tax system to finance sewage treatment plants is being developed.

In the particular case of the island of Curaçao, the implementation of the so called sewage structure plan will demand an investment of US$ 110 million over a period of nine years. This plan does not include the construction of sewerage systems for new housing industrial developments. The necessary funds will be obtained from Government sources through a combined sewage and pollution tax.

To finance the "sewerage structure plan" a household tax of US$ 56 per year will be levied to provide an estimated revenue of US$ 16.7 million over a period of nine years. An additional pollution tax of US$ 33 per household will provide US$ 10 million for the same period. Finally, an amount of US$ 12.8 million will be obtained from the sale of treated sewage waters.

With reference to the Island of Bonaire financing for the sewer structure plan" will require investment of US$ 10 million. Proposals have not yet been completed for the Islands of Saba, St. Eustatious and St. Maarteen.

9.10 Information sources (Topic j)

Caribbean Environmental Health Institute

PO Box 1111
The Morne
Castries, St. Lucia

Telephone: (758) 452 2501
Fax: (758) 453 2721
Email: fclouden.cehi@candw.lc
Contact: Ms Francine Clouden

UNEP-CAR/RCU

14-20 Port Royal Street
Kingston, Jamaica

Telephone: (876) 922 9267
Fax: (876) 922 9292
Email: tjk.uneprcuja@cwjamaica.com
Contact: Mr Tim Kasten

9.11 Case studies (Topic k)

There are a number of excellent case studies for SIDS Caribbean. These are based on papers presented at two recent workshops:

Workshop on Adopting, Applying and Operating Environmentally Sound Technologies for Domestic and Industrial Wastewater Treatment for the Wider Caribbean Region. The workshop was implemented 16-20 November 1998 in Montego Bay, Jamaica by UNEP IETC, Murdoch University of Western Australia and the UNEP Caribbean Regional Coordination Unit in Jamaica.

Workshop on Sustainable Wastewater & Stormwater Management. The workshop was implemented on the 27 – 31 March 2000 in Rio de Janerio, Brazil by UNEP IETC with ABES Brazil.

Only abstracts are included below. The full papers should be consulted for details. The proceedings of the workshops are available from IETC.

9.11.1 Wastewater sector in Trinidad & Tobago: way forward for sustainable development

The author was Manherial Kerof Assisant Director Operations, Water and Sewerage Authority, Trinidad & Tobago.

Abstract

This paper aims to review the present status of the wastewater sector in Trinidad and Tobago and to address concerns regarding the sector's development after years of neglect.

Over 87% of the 1.3 million population of Trinidad and Tobago enjoy a potable water supply whilst only 30% of the population is served by centralized public and private wastewater systems. The total water production (surface and ground) amounts to 780 Mld (172 mgd) while the total volume of wastewater generated equals to 702 (155 mgd). However, the total volume of wastewater collected and treated by centralized wastewater systems averages approximately 150 Mld (33 mgd) or 21.2% of the total wastewater generated. Approximately 100 Mld (22 mgd) of wastewater is collected and treated by WASA through its 12 public wastewater systems and the remaining 50 Mld (11mgd) of wastewater being collected and treated via 148 privately owned and operated (non-WASA) systems. In general, the performance of 90% of all the wastewater plants/systems can be described as poor.

The investment within the wastewater sector has been historically low with an average of 7% of the total consolidated water and wastewater operational expenditure being spent on wastewater operations. Thus, despite the low sewerage rate (i.e. 50% of the water rate) the wastewater sector over the years has been operating at a profit at the cost of deterioration of its assets.

The major issues emerging from the analysis and review of the sector can therefore be summarized as:

- The need for closure of the large gap which currently exists between the volume of wastewater generated and the volume of wastewater collected via the centralized systems

- The need for closure of the large gap between the level of treatment provided and the level of treatment required as per the compulsory Trinidad & Tobago Effluent Standard TTS 417:1993. Less than 1% of wastewater collected and treated conforms to the above standard.
- The need to reduce the proliferation of small, private wastewater systems – a situation which has resulted from the under investment in major Public Wastewater Infrastructure Development schemes over the last 35 years.
- The high investment needs of both the Public & Private (WASA & Non WASA) Wastewater Systems due to the historic under investment in the sector.
- The need for implementation of an effective monitoring and control system to ensure compliance with compulsory Effluent Standards.

The achievement of sustained improvement to the environment and human health in general, requires the development of a long-term strategic vision and action plan for an effective and environmentally sound Wastewater Sector.

This has been recognized at Government level as a draft report on "Development of a strategic plan for the wastewater sector in Trinidad and Tobago (August 1999 by Dilon Consulting Ltd.)", has been prepared by Inter American Development Bank (IADB), under the direction of the Government of Trinidad & Tobago.

The following is recommended in addressing the key issues identified:

- Immediate action on institutional strengthening of the Sewerage Sector,
- Development of a Wastewater Master Plan for Trinidad and Tobago,
- Immediate review and increase in wastewater/sewerage tariffs to appropriate levels with respect to:
- Domestic wastewater discharges (tariffs should be at least equal to that of water),
- Trade effluent discharges
- Development of Trade Effluent Discharge Regulatory Procedures and Monitoring System to control trade effluent discharged into public sewerage systems,
- The establishment and implementation of a national Pollution Control and Monitoring Program to ensure the compliance of all wastewater systems – both public as well as private sector systems.

As a first step towards addressing the needs of the Sector, approval has been granted for the creation of a Wastewater Division within WASA. Further, the current investment trends also indicate a positive change in direction from the one of past neglect. However, further work is needed and the government of Trinidad & Tobago is committed towards improving the quality of wastewater services in the country and to the establishment of a sound and sustainable wastewater sector.

9.11.2 The Bahamas Water and Sewerage Corporation, Water Resources Management Unit (WRMU): Sustainable Wastewater and Storm Water Management.

The authors involved were Philip S. Weech, (Senior Hydrologist B.A, MSc., MIWEM, AWRA, AWWA), Glen F. Laville (AGM / Engineering & Construction, B.S.C.E, CWWA) and John A. Bowleg II (Assistant Hydrologist B.S.C.E, ASCE).

Abstract

The purpose of this paper is to show that sustainable water sector development in the Bahamas must take advantage of the peculiar hydrodynamics of the local geology, hydrology and marine dynamics. The "true" economic cost of development, as well as the long term operational and maintenance burdens of public infrastructure must be borne in mind. The model of sustainable development being proposed and explained in the paper and the model follows the notion that storm water and wastewater streams should be separated.

9.11.3 Cuba: Study cases about interrelationship sanitation, environment and sustainable management of wastewaters.

The author of the paper is Dr. Cristóbal Félix Díaz Morejón of the Environmental Policy Directorate, Ministry of Science, Technology and Environment.

Abstract

The work mainly introduces the problem of the wastewater management, reflecting a brief panorama of the country's situation, as much in the reception as in its conduction and final disposition.

A principal case of study: the application of solution schemes of simplified sewer system or of low cost, to the local conditions; and are presented too, two also related cases: the creation of a National Center of Appropriate Technologies for Sanitation (SANITEC) that lead to the country in the search of economic solutions that protect the environment and with high social acceptance; and the particular application of stabilization ponds for the wastewater treatment coming from tourist hotels built in two keys.

The main case possesses the following characteristics:

- Support of UNICEF and the local governments.
- Work of a multidisciplinary team in all phases: planning, project and construction.
- Wide participation of the town inhabitants, from the conception of the idea and project, until their construction and maintenance (that reduces the operational costs significantly). Systematic consults with the formal and not formal leaders, and in general with the residents.
- Application of more sustainable and economical technology, with alternatives adapted to the local conditions.
- Solution to critical environmental problems in the community that provoke dangers to the human health and cause strong contamination in the river Guaso, where wastewater spilled without control.
- Solution to the floods caused by the rainwater.

The second case constitutes a simple presentation, with the objective to offer to the participants in the Workshop the possibility to share in a future the knowledge that SANITEC accumulates.

The third case constitutes a casuistic solution to the treatment of residual liquids in small islands with high development of the tourism, through the employment of stabilization ponds that at the moment have had good values of efficiency, and whose treated waters are used in the irrigation of the hotels gardens (reuse of the waters), like part of a complete cycle

dedicated to avoid the contamination of the coastal and marine ecosystems, that have invaluable values for the tourist activity. Their reading may be of interest for the participants.

9.11.4 Barbados: Sustainable Stormwater Management

The paper is entitled Harnessing and Harvesting a Natural ResourceTerrol and authored by T. Inniss, Acting head of Drainage unit, Ministry of Public Works & Transport.

Abstract

Sustainable Stormwater and Wastewater Management is an issue that should always be in the forwards of our mind. To attain this within the limits of our own social and economic development it is necessary to practice sustainability in the light of a common world market and liberalized trade. It is effective Management of available resources that has the potential to achieve the forgoing.

9.11.5 An Exercise in Appropriate Technology – Case Study of a Typical Village in St. Lucia

The paper is titled Small Community Wastewater Treatment Systems authored by Francine Clouden from the Caribbean Environmental Health Institute in St. Lucia.

The village is located on the East Coast of St. Lucia. The soil type is extremely rocky in some areas and the ground water table is high, as the main part of the villages is located in a flood plain close to the ocean. Houses are located very close to each other and the development is random and unplanned.

The total population of the village is 4440 (1992 census) with a total number of households of 1179.

St. Lucia Water and Sewerage Authority (WASA) supplies the potable water, with intakes located in the vicinity. Treatment consists of a stone filter, sand filters (in parallel), and chlorination. 23% of the population are supplied by standpipes in the neighborhood, 50% have a private supply (i.e. piped water in the home) and 27% have none available close by i.e. no standpipe within walking distance. Because of the topography regularity of the supply is compromised.

Current excreta disposal practices are as follows: 11% pit latrines; 13% pail latrines; 34% water closet and septic tank; 42% none on premises. This forty-two percent of the residents (600 persons) use the public facilities provided of which there are five with a total of 22 toilets and 24 showers operational.

Most of the facilities were built 15 to 20 years ago and include showering and laundering facilities. All the facilities operate with the same system. The grey water is discharged either directly into the sea or into a surface drain that runs into the sea. Excreta (“black water”) is treated in a septic tank. The effluent from the septic tank is disposed of into a soakaway through a pipeline. A pump truck is used to remove the sludge remaining in the septic tank. The regularity of this is dependent on the availability of the pump truck, which is sporadic due to frequent breakdowns.

At one of the facilities located at the beach the use of the toilets was discontinued in order to avoid pollution caused by a crack in the pipe of the septic tank and the proximity of the corresponding soakaway to the sea. Bathing in the 4 shower rooms and laundry is still practiced and the grey water goes directly into the sea.

The newest facility, built in 1994, near the fishing port of the village is in comparatively good condition. It is equipped with 8 toilets and 8 shower rooms. As the caretaker reported the only problem encountered is frequent breaking of the toilets cisterns because domestic fittings have been used.

Another facility is elevated, therefore some problems are encountered with its water supply. At certain times, especially in the morning the water supply fails in the whole facility.

The remaining two facilities are working well. Both are centrally located, where most of the houses have no private amenities.

Moreover the two facilities at the beach have night soil chutes to prevent the residents from throwing their night soil into the river. Unfortunately the use of the night soil chutes had to be discontinued due to the residents disposing of solid waste into them. This led to frequent choking which caused the maintenance cost to rise. Additionally, the instruction board for proper use of the chutes has gone missing from one of the facilities.

Most of the public facilities have in common that they are not maintained properly, have often fallen into disrepair and are subject to vandalism by the residents.

The result of most of these problems is that the village has a high incidence of diarrhaoel and other enteric diseases such as Typhoid Fever and Dysentery. A recent survey (stool examinations) revealed that 65% of the school age children in the village were infested with some type of Helminthes. Monitoring of the potable water supply over a two-and-a-half week period during the rainy season showed that the quality of drinking water was quite good. The conclusion may be drawn therefore that poor sanitation, hygiene and excreta disposal are the main causes of the high incidence of disease.

The systems currently being used in the village are all deemed “appropriate technology” yet they still failed. The information just presented suggests that the problem in the village cannot be solved solely by a technical approach such as construction of Pit Latrines or improvement in water supply. It would be relatively simple to recommend and design such. Other short-term solutions such as repair and rehabilitation of public facilities can also be implemented but a more holistic approach involving all stakeholders needs to be adopted. The previous failure of the other projects, such as the night soil chutes and the lack of regard of residents towards the public facility need to be examined and addressed before any solution can be successfully implemented. The practices of the reverting to using the bushes or rivers when the water supply is bad indicates a general lack of understanding on the part of residents of basic sanitation and hygiene issues, and their link to the incidence of illness and diseases.

We can therefore conclude that the term “appropriate technology” should refer not only to the technical solution but should encompass a complete system that addresses social, cultural and economic issues.

Appendix 1
Health Effects Associated with Wastewater and Excreta

1. Overview

The failure to properly treat and manage wastewater and excreta world-wide is directly responsible for adverse health and environmental effects. Human excreta has been implicated in the transmission of many infectious diseases including cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis, and schistosomiasis. WHO estimates that 2.2 million people die annually from diarrhoeal diseases and that 10% of the population of the developing world are severely infected with intestinal worms related to improper waste and excreta management (WHO, 2000a; Murray & Lopez, 1996). Human excreta-transmitted diseases predominantly affect children and the poor. Most of the deaths due to diarrhoea occur in children (accounting for nearly two million) and in developing countries (WHO, 1999a).

Infectious agents are not the only health concerns associated with wastewater and excreta. Heavy metals, toxic organic and inorganic substances also can pose serious threats to human health and the environment. Nitrates from the wastes can build up to high concentrations in groundwater and cause methaemoglobinaemia when consumed by bottle-fed infants. Nutrients may cause eutrophication in receiving water bodies potentially leading to cyanobacterial and other harmful algal blooms and the production of toxins by these organisms. Other chemicals such as pharmaceutical residues and potential endocrine disrupting substances have been identified in wastewater and excreta at low concentrations. Although the likelihood of health effects from exposure to these substances at these concentrations is assumed to be small, further research is needed to assess the actual health risks.

Estimates suggest that less than 5% of all sewage in developing countries receives any treatment before it is discharged into the environment (World Resources Institute, 1998). Industrialized countries also need to improve their sewage, excreta, and sludge management practices. For example, in the United States, the number of waterborne disease outbreaks and the number of affected individuals per outbreak has increased since 1940 (Hunter, 1997). Similarly, water quality monitoring of major European rivers indicates that average coliform levels have been steadily increasing for decades (Meybeck et al., 1990).

Despite more investment in water and sanitation projects in the last two decades, the total number of people without access to water and sanitation services remains stubbornly high, particularly in urban and peri-urban areas (WHO, 1997a). Worldwide efforts are required to reduce the transmission of waterborne diseases and decrease the flow of nutrients into areas prone to eutrophication and toxic algal blooms.

2. Economic Aspects of Health Effects

The failure to properly manage and dispose of wastewater and excreta has enormous financial implications. The costs of medical treatment and loss of productivity associated with diseases caused by exposure to contaminated food and water are most certainly high but have never been accurately estimated. Determining these costs is extremely difficult because there are so many different variables to consider. It is estimated that there are 4 billion cases of diarrhoea and 1.5 million acute cases of hepatitis A each year throughout the world (Murray & Lopez, 1996; WHO, 2000b) but assessing how many of these cases are directly connected to improper wastewater and excreta management/disposal is challenging. However, when different types of health interventions are evaluated it may be possible to provide a rough estimate of the percentage of these illnesses that can be attributed to improper waste and excreta management. For example, Esrey et al. (1991), found that sickness from diarrhoea was reduced by 25 – 33%, schistosomiasis was reduced by 77%, trachoma was reduced by 25%, and overall child mortality was reduced by 60% when well-designed basic water, sanitation and hygiene interventions were implemented at the community level. The World Bank (1993) estimated 40% reductions for both diarrhoea and intestinal worm infections using similar interventions.

In general, estimates of the costs that have been made for illnesses associated with improper waste management are country specific or are valid only for selected exposure pathways e.g., marine contamination-related diseases (Shuval, 2000). For example, in the US it has been estimated that waterborne diseases cost the country between 3 and 22 billion dollars per year in medical bills and lost productivity (Bennett et al., 1987; Murphy, 1999). In China illnesses related to water contaminated by untreated wastewater and excreta are thought to cost the country at least 3.9 billion dollars per year (World Bank, 1997). Shuval (2000) estimates that wastewater contamination of the marine environment is responsible for 250 million clinical cases of mild gastroenteritis and upper respiratory disease through recreational and other water contact, 2.5 million clinical cases of infectious hepatitis (Hepatitis A and E) acquired from consumption of contaminated seafood, and 100,000 – 200,000 cases of intoxication with algal biotoxins from consumption of contaminated seafood. Overall, these marine contamination-related diseases are thought to have an estimated economic impact of 13 billion dollars worldwide. WHO is also currently evaluating the estimated disease burden and associated costs of worldwide faecal-oral disease transmission related to improper wastewater and excreta disposal/management.

3. Health Effects Associated with Wastewater and Excreta

Wastewater and excreta consist of water (approximately 99%), micro-organisms (including human pathogens), and organic and inorganic substances including nutrients. The microbial pathogens (bacteria, helminths, protozoa, and viruses), heavy metals, nutrients, and organic compounds contained in wastewater and excreta pose a potential threat to human health and the environment. When improperly or untreated wastewater and excreta are released into the environment these substances can impact human health through the consumption of contaminated water, through the food chain, through poor personal hygiene, and through recreational or other contact with contaminated waters.

4. Pathogens

Pathogenic viruses, bacteria, protozoa and helminths (see table 1) are released from the bodies of infected persons in their excreta and may be passed on to others via either the mouth (e.g., through the drinking of contaminated water or eating contaminated vegetables/food) or the skin (as in the case of the hookworms and schistosomes). Excreta and wastewater generally contain high concentrations of excreted pathogens, especially in countries where diarrhoeal diseases and intestinal parasites are particularly prevalent.

Infectious diseases caused by pathogenic bacteria, viruses, protozoa or parasites are the most common and widespread health risks associated with drinking-water. Faecal contamination of drinking water is responsible for many disease outbreaks worldwide. The pathogens that most frequently cause disease include *Salmonella* spp., *Shigella* spp., pathogenic *Escherichia coli*, *Vibrio cholerae*, *Yersinia enterocolitica*, *Campylobacter jejuni*, hepatitis A viruses (and other viruses in table 1), *Giardia* spp., *Cryptosporidium* spp., and *Entamoeba histolytica* (WHO, 1993a). Most of these pathogens are distributed worldwide but outbreaks occur more frequently and endemicity is higher in areas where access to good quality water supplies and sanitation is limited.

In the 1990s, cholera reemerged as a major infectious disease as epidemics were reported in Africa, Asia, and South America. From 1991 to 1996 WHO estimated that there were between 70,000 and 160,000 cholera cases in Africa alone (WHO 1997b). The 1991 epidemic in Latin America caused 750,000 cases and 6500 deaths (PAHO, 1991). Cholera is primarily spread via faecally contaminated water and food. In 1970, a cholera epidemic in Jerusalem was traced back to the consumption of salad vegetables irrigated with raw wastewater. Health authorities isolated the same cholera strain from infected individuals, sewage, irrigated soil, and the irrigated produce. The epidemic quickly subsided after the authorities confiscated the vegetables grown with the untreated wastewater (Shuval et al., 1986). Cholera infections have also been linked to the consumption of contaminated seafood in the United States (CDC 1991; CDC 1996) and elsewhere. Although there is evidence that toxigenic strains of *Vibrio cholerae* have been spread from different regions by contaminated ballast, bilge water, and sewage dumped by ships from epidemic areas (McCarthy et al., 1992), it is unlikely that cholera will become endemic in areas with high standards of hygiene and sanitation.

Parasitic protozoa such as *Cryptosporidium parvum* and *Giardia lamblia* have recently been recognized as important causes of water and food-borne disease outbreaks associated with faecal contamination. These pathogens are particulary difficult to control because they are resistant to chlorine disinfection, persist in the environment, infect other animal hosts and may be difficult to diagnose and treat (WHO, 1993a). Cryptosporidium outbreaks have occurred worldwide due to contamination of drinking water, recreational waters and food. Serological studies of different populations indicate that prevalence of Cryptosporidium infection is very high. For example, in Anhui China, over half of the children by age five demonstrated antibodies to Cryptosporidium. In a poor area of Brazil, over 90% of the children developed antibodies to Cryptosporidium by the age of one. In some studies conducted in the United States, 17 – 32% of people exhibited serological evidence of Cryptosporidium infection by the time they became adults (Zu et al., 1994; Ungar et al., 1986; Ungar et al., 1988; Ungar et al., 1989).

Contamination of drinking water sources is also a problem in developed countries. In May 2000, an *E. coli* 0157:H7 outbreak occurred in Ontario Canada. In the outbreak more than 1000 people were infected and seven people died (Kondro, 2000). Similarly, in 1993, a cryptosporidium outbreak in Milwaukee, Wisconsin, U.S.A. affected approximately 400,000 consumers and caused 54 deaths – predominantly in immunocompromised persons (Kramer et al., 1996; Hoxie et al., 1997). Viruses, particularly Norwalk viruses and other human caliciviruses, were estimated to cause a large number of waterborne gastroenteritis outbreaks – as many as 6 million cases per year in the United States (Bennett et al., 1987).

Contact with faecally contaminated recreational waters has been associated with numerous disease outbreaks and unexpectedly high infection rates worldwide. Bathers and recreational water users frequently report gastro-intestinal symptoms, skin irritation, ear, nose, and throat infections, and respiratory infections (WHO, 1998). Gastro-intestinal symptoms have been directly correlated to concentrations of faecal bacteria found in fresh and marine waters *(e.g., Escherichia coli*, enterococci, and faecal streptococci) (Prüss, 1998). From 1997 to 1998, 32 disease outbreaks associated with recreational water were reported to the United States Centers for Disease Control. Of the gastroenteritis cases, half were caused by Cryptosporidium, 22% by bacteria and 11% by viruses (Barwick et al., 2000). Overall, Shuval (2000) estimates that, worldwide, there are 250 million clinical cases per year of mild gastroenteritis and upper respiratory disease due to bathing in contaminated waters.

Many types of pathogenic viruses have been identified in recreational waters. Griffin et al. (1999) found either enteroviruses, hepatitis A viruses, or norwalk viruses at 95% of 19 sampling sites in surface waters around the Florida Keys. Levy et al. (1998) found direct evidence of calicivirus outbreaks associated with recreational surface-water exposure.

Food that comes in contact with untreated or partially treated wastewater and excreta also can spread infectious diseases. Foods that are eaten raw or partially cooked are especially associated with the transmission of faecal-oral diseases. For example, some shellfish (such as mussels, oysters, and clams) obtain their food by filtering large quantities of water and are therefore particularly susceptible to contamination. Excreta-related human pathogens and heavy metals are taken in with the food particles and can be concentrated in the tissues. Shellfish are also frequently eaten raw or partially cooked. In 1988, the consumption of contaminated shellfish in Shanghai China led to an outbreak of Hepatitis A involving approximately 300 000 cases (Lees, 2000). Norwalk viruses have also been implicated in numerous disease outbreaks associated with the consumption of raw oysters (CDC, 2000).

Fish, and non-filter feeding shellfish (crabs, lobsters, prawns, shrimps) grown in faecally contaminated water containing high levels of human pathogens can concentrate the pathogens in their intestinal tracts and on their skin surfaces. When concentrations of faecally derived bacteria exceed a certain level they can be found in the muscle tissues of the fish. Infection may occur when the contaminated fish is consumed raw or lightly cooked. Cholera has been transmitted through contaminated fish and crabs in Guam and the United States respectively (CDC, 1996). Food handlers may also be at risk during preparation of the contaminated product.

Depuration, the transfer of fish or shellfish to non-contaminated water to cleanse the fish and shellfish of contamination prior to harvest, is widely practiced but, does not reliably remove bacteria or viruses from fish or shellfish muscle tissue.

The use of inadequately treated wastewater in irrigation is especially associated with elevated prevalence of intestinal helminth infection. For example, in Mexico, irrigation with untreated or partially treated wastewater was directly responsible for 80% of all *Ascaris* infections and 30% of diarrhoeal disease in farm workers and their families. However, when wastewater was retained longer in a series of retention ponds there was minimal risk of either *Ascaris* infection or diarrhoeal disease (Cifuentes et al., 2000). *Ascaris* infections in West Jerusalem were associated with the consumption of raw vegetables that were irrigated with untreated wastewater. When supplies of these vegetables were cut off, the number of *Ascaris* infections in the population dramatically decreased (Shuval et al., 1986).

Trematode infections are caused by parasitic flatworms (also known as flukes) that infect humans and animals. Infected individuals transmit trematode larvae in their faeces. Infections with trematode parasites can cause mild symptoms such as diarrhea and abdominal pain or more rarely, debilitating cerebral lesions, splenomegaly and death depending on the parasite load. In many areas of Asia where trematode infections are endemic, untreated or partially treated excreta and nightsoil are directly added to fish ponds. The trematodes complete their lifecycles in intermediate hosts and subsequently infect fish, shellfish, or encyst on aquatic plants. Humans become infected when they consume the fish, shellfish, or plants raw or partially cooked. WHO estimates that more than 40 million people throughout the world are infected with trematodes and that over 10% of the global population is at risk of trematode infection (WHO, 1995). Proper treatment of wastewater and excreta before it is introduced into fish ponds and thoroughly cooking fish, shellfish and plants are methods of breaking the lifecycle of these parasites.

Table 1: Pathogens Found in Untreated Municipal Wastewater and Excreta

Agent	Disease
Bacteria	
Campylobacter jejuni	Gastroenteritis, long term sequelae (*e.g*. arthritis)
Escherichia coli	Gastroenteritis
E. coli 0157:H7	Bloody diarrhoea, hemolytic uremic syndrome
Helicobacter pylori	Abdominal pain, peptic ulcers, gastric cancer
Legionella pneumophila	Legionnaire's disease
Leptospira (spp.)	Leptospirosis
Salmonella (many serotypes)	Salmonellosis, long term sequelae (*e.g*. arthritis)
Salmonella typhi	Typhoid fever
Shigella (several serotypes)	Shigellosis (dysentery), long term sequelae (*e.g*. arthritis)
Vibrio cholerae	Cholera
Yersinia enterocolitica	Yersiniosis, long term sequelae (*e.g*. arthritis)
Helminths	
Ascaris (roundworm)	Ascariasis
Ancylostoma (hookworm)	Hookworm
Clonorchis (liver fluke)	Clonorchiasis
Fasciola (liver fluke)	Fascioliasis
Fasciolopsis (liver fluke)	Fasciolopsiasis
Paragonimus (lung fluke)	Paragonimiasis
Schistosoma (blood fluke)	Schistosomiasis, Bilharzia
Trichuris (whipworm)	Trichuriasis
Taenia (Tapeworm)	Taeniasis
Protozoa	
Balantidium coli	Balantidiasis (dysentery)
Cryptosporidium parvum	Cryptosporidiosis, diarrhoea, fever
Cyclospora cayetanensis	Persistent diarrhoea
Entamoeba histolytica	Amebiasis (amebic dysentery)
Giardia lamblia	Giardiasis
Viruses	
Adenovirus (many types)	Respiratory disease, eye infections
Astrovirus (many types)	Gastroenteritis
Calicivirus (several types)	Gastroenteritis
Coronavirus	Gastroenteritis
Enteroviruses (many types)	Gastroenteritis, various
Coxsackie A	Herpangina, aseptic meningitis, respiratory illness
Coxsackie B	Fever; paralysis; respiratory, heart, and kidney disease
Echovirus	Fever, rash, respiratory and heart disease, aseptic meningitis
Norwalk virus	Gastroenteritis
Poliovirus	Paralysis, aseptic meningitis
Hepatitis A virus	Infectious hepatitis
Hepatitis E virus	Infectious hepatitis
Parvovirus (several types)	Gastroenteritis
Reovirus (several types)	Not clearly established
Rotavirus (several types)	Gastroenteritis

Sources: National Research Council, 1998; Hurst et al., 1989; Sagik et al., 1978; and Edwards, 1992.

5. Chemicals and Nutrients

The health risks associated with chemicals found in wastewater and sludge may need to be given more attention, particularly as the pace of industrialization increases in developing countries. In many areas, municipal wastewater and industrial wastes are combined, creating a potentially dangerous mixture of toxic substances that must be handled carefully (see table 2).

Municipal sludge may contain high concentrations of heavy metals such as cadmium, lead, nickel and chromium. When industrial wastewater is also present concentrations of these metals can be 10 to 20 times higher (Chang, Page and Asano, 1995). In 1983, it was estimated that incineration of sewage sludge worldwide introduced between 3 and 36 tonnes/year of cadmium into the atmosphere (Nriagu and Pacyna, 1988). This cadmium eventually is deposited to terrestrial and aquatic environments. Heavy metals such as cadmium and mercury concentrate in the tissues of many filter-feeding shellfish, fish, and in some cases terrestrial plants (WHO, 1992; WHO, 1989) and thus can pose significant health threats to consumers of these products. For example, Grössman (1988 in WHO, 1991) found elevated levels of nickel in green vegetables, cabbage, onions, beans and peas grown on soils contaminated with nickel from sewage sludge application.

Organic chemicals found in wastewater and sludge may also cause adverse health effects, but direct evidence is limited. However, this does not mean that there are no serious health effects associated with use of water contaminated with industrial wastes. Rather, it is a reflection of the difficulty of associating chronic exposure of chemicals and chemical mixtures to diseases with long latency periods. In some parts of China where irrigation with wastewater heavily polluted with industrial wastes has occurred for many years, health effects have been observed. For example, wastewater irrigation was associated with a 36% increase in hepatomegaly (enlarged liver), and a 100% increase in both cancer and congenital malformation rates compared to control areas (Yuan, 1993).

To minimize adverse health and environmental effects from these components, industrial wastes should be adequately pre-treated to remove these chemicals or should be treated separately from municipal wastewater and excreta.

Poor irrigation practices with untreated or partially treated wastewater also impact the quality and safety of groundwater in shallow aquifers and surface waters that may supply drinking water. Wastewater related nitrate contamination of aquifers has been extensively documented in both developed and developing countries. High concentrations of nitrates in drinking water can cause methaemoglobinaemia ("blue baby" syndrome). Numerous cases of methaemoglobinaemia due to nitrate exposure in bottle-fed infants have been reported in Eastern Europe and the United States over the last ten years – including several infant deaths (Knobeloch et al., 2000). It has been suggested that chronic exposure to nitrates in drinking water may also be linked to cancer, thyroid disease and diabetes (Knobeloch et al., 2000).

Excessive nutrients (primarily nitrogen and phosphorus), in wastewater, sludge and excreta, may contaminate surface waters and can cause eutrophication. Eutrophication of freshwater sources may create environmental conditions that favor the growth of toxin-producing cyanobacteria. Toxins produced by cyanobacteria can cause gastroenteritis, liver damage, nervous system impairment, and skin irritation. Chronic exposure to cyanobacteria toxins has been associated with liver cancer in animals and may cause similar effects in humans (Chorus and Bartram, 1999). Health problems associated with cyanotoxins have been documented in several countries including Australia, Brazil, Canada, China, England, USA, and Zimbabwe. In China, Ling (2000) found that liver cancer mortality was nearly six times higher in people who obtained their drinking water from eutrophic ponds where high concentrations of cyanobacterial toxins (microcystins) were present than in people who obtained their drinking water from deep wells. Exposure to these toxins has usually been through contaminated drinking water or recreational contact with the water. However, it is also likely that consumers of contaminated freshwater fish or shellfish might be exposed to these toxins (Chorus and Bartram, 1999).

Table 2:Chemicals of Health Concern Found in Untreated Municipal Wastewater and Excreta

Chemical	Health Effect
Halogenated Compounds	
Chloroform	Skin irritation, nausea, embryo/fetotoxic
DDT	Nervous system damage, cancer (?)
Di and tri-chlorobenzenes	Liver, kidney, and blood damage
Tetrachloroethane	Liver damage, nausea
Heavy Metals	
Arsenic	Gastrointestinal, skin, and nerve damage, cancer
Cadmium	Gastrointestinal, kidney and lung damage
Chromium	Lung and skin damage, cancer
Lead	Nervous and immune system, and kidney damage, embryo/fetotoxic
Mercury	Brain and kidney damage, embryo/fetotoxic
Nickel	Lung, brain, kidney, liver, spleen and skin damage, cancer
Inorganic Chemicals	
Cyanide	Brain and heart damage, shortness of breath, death
Flouride	Dental and skeletal fluorosis
Hydrogen Sulfide	Nausea, vomiting, mucous membrane irritation
Nitrate	Methaemoglobinaemia
Nutrients	
Nitrogen Phosphorus	Cause eutrophication which facilitates the growth of toxin-producing cyanobacteria and other harmful algae
Organic Chemicals	
Benzene	Anemia, dizziness, leukemia
Phenol	Irritation of skin, eyes, and gastrointestinal tract, systemic toxicant
Toluene	Brain and kidney damage
Xylene	Confusion, dizziness, memory loss, embryo/fetotoxic
Other Chemicals	
Endocrine disruptors	Reproductive/developmental effects in wildlife, various potential effects in humans
Pharmaceuticals	Reproductive/developmental effects in wildlife, various potential effects in humans

Sources: Chang, Page, and Asano, 1995; National Research Council, 1998; WHO, 1999c; WHO, 1992; WHO, 1991; WHO, 1989; ATSDR, 2000.

There is also some evidence to indicate that nutrient enrichment of marine waters is partially responsible for other (i.e. non-cyanobacterial) toxic algal blooms (Epstein, et al. 1993). Toxins produced by these algae accumulate in the flesh of filter-feeding shellfish. When the toxins in the shellfish are consumed a variety of illnesses may result, including; paralytic shellfish poisoning, diarrhoeic shellfish poisoning, amnesic shellfish poisoning, ciguatera poisoning and neurotoxic shellfish poisoning (Hallegraeff, 1993). Several of these toxins can cause serious health effects – even death in certain circumstances (WHO, 1986).

In the last several years chemicals that mimic hormones or have anti-hormone activity, and interfere with the functioning of endocrine systems in various species have been identified in municipal wastewater. Endocrine disruptors as they are known, derive from many sources including pesticides, persistent organic pollutants, nonionic detergents and human pharmaceutical residues. Many of these substances are resistant to conventional wastewater treatment and may persist in the environment for some time (National Research Council, 1998). Human health effects potentially linked to exposure to these chemicals include: breast, prostate and testicular cancer; diminished semen quantity and quality; and impaired behavioural/mental, immune and thyroid function in children. Although direct evidence of adverse health effects in humans is lacking, reproductive abnormalties, altered immune function, and population disruption potentially linked to exposure to these substances has been observed in amphibians, birds, fish, invertebrates, mammals, and reptiles (WHO, 1999b).

6. Treatment and Risk Management

There are many ways in which adverse health effects to humans from the release of untreated/inadequately treated municipal wastewater and excreta into the environment can be minimized. Some of the most important methods include proper wastewater and excreta treatment and disposal, waste minimization (e.g., reducing the volume of the wastes or the use of toxic chemicals), providing separate treatment or diversion of wastewater and sludge with high concentrations of toxic chemicals (industrial wastes), protection of water sources, restriction of shellfish harvesting and bathing in polluted waters, safe water handling and storage, and improving personal hygiene including hand washing with soap and safe disposal of faeces.

This document will focus on the proper treatment and disposal of wastes (i.e., the removal or significant reduction of harmful components from wastes and disposal of wastes so that humans will not be exposed to harmful substances) and improving personal hygiene.

6.1 Treatment options (see table 3)

Human pathogens in municipal wastewater and excreta generally pose the greatest threat to human health. Wastewater and excreta should be effectively treated to reduce threats to human health.

Most of the world's population does not have access to adequate sanitation. Conventional sanitation relies on centralized sewerage systems and requires large amounts of water to carry the wastes away. This type of approach may work well in developed countries and large cities but is impractical for many other locations. The cost of a sewerage system (which is usually more than four times that of on-site alternatives) and its requirement of a piped water supply preclude its adoption in the many communities in developing countries that lack adequate sanitation (Franceys, et al. 1992). On-site disposal, can effectively protect public health, facilitates the reuse of valuable waste components (nutrients, organic matter, and water), keeps the waste where it is produced, reduces contamination with toxic chemicals, and generally is the least expensive alternative. On-site disposal alternatives range from simple composting latrines to complex bioreactor systems. Refer to Source Book.

Where land is available at low cost and sewerage is conveyed to centralized locations, well-designed waste stabilization pond (WSP) systems have proven to be very effective in treating wastes. The advantages of WSP systems are that they cost little to run, are simple to maintain, produce small volumes of sludge, facilitate waste reuse and are good at removing pathogens – especially helminths which are not adequately removed in most primary and secondary treatments.

Conventional wastewater and excreta treatment strategies (primary and secondary levels) in developed countries have traditionally focused on the removal of suspended solids and pollutants that used oxygen in the receiving waters to decompose (Biological Oxygen Demanding substances or BOD) and less on the reduction of pathogens and nutrients. These processes usually are expensive to operate due to the large energy, skilled labor, infrastructure, and maintenance requirements. Tertiary treatments must be added to the process to effectively reduce pathogen and nutrient levels. Frequently different tertiary treatments may be used in combination to reduce pathogen levels to very low or undetectable levels. For example, a filtration step (i.e., microfiltration, ultrafiltration, multimedia filtration) or reverse osmosis may be combined with disinfection. Addition of further treatment steps however, significantly increases the cost and complexity of the process.

Table 3: Removal Efficiencies of Excreted Microbes

Treatment Process	**Removal (log_{10} Units)**			
	Bacteria	**Helminths**	**Protozoa**	**Viruses**
Primary	0 - 1	0 – 2	0 – 1	0 - 1
Primary + chemical coagulation	1 - 2	1 – 3	0 – 1	0 - 1
Secondary Treatments				
Activated sludge + 2^B sedimentation	0 - 2	0 – 2	0 – 1	0 - 1
Biofiltration	0 - 2	0 – 2	0 – 1	0 - 1
Aerated lagoon + settling pond	1 - 2	1 – 3	0 – 1	1 - 2
Oxidation ditch	1 - 2	0 – 2	0 – 1	1 - 2
Waste stabilisation ponds	1 - 6	1 – 3	1 – 4	1 - 4
Effluent storage reservoirs	1 - 6	1 – 3	1 – 4	1 - 4
Tertiary Treatments				
Chlorination (free)	2 - 6	0 – 1	0 – 3	0 - 4
Combined chlorine	1 - 2	ND	1 – 2	1 - 2
Ozone disinfection	2 - 6	0 – 1	1 – 2	0 - 4
UV disinfection	2 - 6	ND	1 – 3	2 - 4

ND= No Data

Sources: Feachem et al., 1983; Rose et al., 1996; Rose et al., 1997; National Research Council, 1998; Karimi, et al., 1999; Clancy et al., 1998; Lazarova et al., 2000; Sobsey, 1989

6.2 Treatment of excreta and sludge

Sludge that is produced from municipal wastewater treatment processes also must be treated carefully before it can be safely disposed of or used as a fertiliser. Many of the organic and inorganic chemicals as well as the pathogens are concentrated in the sludge. When industrial wastewater is mixed with municipal wastewater high concentrations of toxic chemicals may be found in the sludge turning it into a hazardous waste that requires special disposal to limit adverse health and environmental effects. Additionally, toxic chemicals can interfere with the biological processes that are used to treat the wastes thus reducing the effectiveness of the treatment. Therefore, it is imperative to separate toxic industrial wastes from municipal wastes before treatment to preserve sludge reuse options and protect public health.

Helminth eggs are extremely durable and can remain viable for long periods of time. Therefore, excreta and sludge treatments usually require storage periods for many months to ensure helminth egg inactivation. Storage times can be reduced when the excreta and sludge are allowed to digest at higher temperatures. WHO recommends each of the following procedures for the treatment of sludge, excreta, and nightsoil to minimise adverse health effects prior to sludge disposal or use of sludge or excreta as a fertiliser (Mara and Cairncross 1989, Helmer and Hespanhol, 1997):

- Storage for 12 months at ambient temperatures (warm climates), or
- Batch thermophilic anaerobic digestion at 50 – 55°C for 13 days, or
- Forced-aeration co-composting of excreta with domestic refuse for one month (temperature should rise to 55 – 60°C), followed by 2 – 4 months of maturation, or
- Raw sludge and excreta can be safely applied to the land by subsurface injection, or placed in trenches and covered with at least 25cm of soil before crops are grown (where soil conditions and the depth to the water table permit), or
- Liquid nightsoil can be stored for one week and applied to land but the settled sludge which may contain high concentrations of helminth eggs should be stored for at least a year or digested as above.

6.3 Hygiene

Improving personal hygiene generally requires major behavioural changes (and an adequate supply of water), but is one of the most important steps in minimising adverse health effects from municipal wastewater and excreta. Numerous epidemiological studies have documented the importance of washing hands with soap and water. This act alone, can cut the transmission of diarrhoeal disease by a third (WHO, 1993b; Esrey et al., 1985; Esrey and Habicht, 1986; Huttly, 1990; Esrey et al., 1991). Additionally, it is critically important to dispose of faeces, particularly children's faeces, in a safe manner. Children frequently are the victims of diarrhoeal disease and other faecally/orally transmitted illnesses, and thus may act as sources of pathogens. Getting children to use sanitation facilities (or designing child-friendly toilets), and implementing school sanitation programmes, are important interventions for reducing the spread of disease associated with waste and excreta (WHO, 1993b).

7. Conclusion

Poor wastewater and excreta disposal continues to be responsible for a significant proportion of the world's infectious disease burden. This burden is not distributed equally, waterborne illnesses predominantly affect the poor and the young. However, when basic water, sanitation, and hygiene interventions are applied, waterborne illnesses can be effectively reduced. Moreover, low cost interventions can be implemented to reduce the transmission of many diseases. For example, the safety of drinking water can be improved by protecting sources from faecal contamination and disinfection. Wastewater and excreta can be treated in waste stabilization ponds to reduce pathogen concentrations and facilitate the reuse of nutrients. Hygiene education and the promotion of hand-washing is also extremely effective in reducing faecal-oral disease transmission. As poor countries industrialize, it is important to minimize the production of toxic chemicals and to treat industrial wastes separately when high concentrations of dangerous chemicals are present.

Reducing the adverse health effects associated with wastewater, sludge and excreta is possible but takes sustained effort at the individual, community and national levels. Additionally more emphasis must be found on finding sustainable approaches for reducing health hazards associated with wastewater, sludge and excreta, and at the same time, closing the nutrient cycle and protecting limited fresh water sources and the environment.

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Appendix 2
Costs of Wastewater Management

Cost is an important consideration in the selection of technology. Decision makers need to know about the relative costs of technologies, so that a decision to select a particular technology can be based on sound financial and economic considerations. Cost alone should, however, not be the sole determining factor in the selection of technology. Environmental impact of the technologies, such as contamination of groundwater, should also be considered. Appropriateness of the technology in the context of the availability of skilled personnel to operate and maintain it, as well as other social and cultural factors need to be taken into account.

Information on capital cost and the cost for operation and maintenance for a wide range of technologies is available, although much of the information is derived from experience in a limited number of countries. Extrapolation of the data to other locations is fraught with difficulty. Relative costs may be sufficient to narrow the choice of technology, although it must be borne in mind that the relative values may change from location to location dependent of specific local conditions. Cost of land and of labour in particular can vary considerably. The information provided here should therefore be used only as a guide of relative costs. Actual costs for a particular location and community should be ascertained from suppliers of equpment, materials and labour.

Table 1 indicates the relative costs for a number of technologies described in the Source Book. The information is derived from data collected for a computerised decision support system SANEX (Source Book Section 2 (8.3)). An advantage of computerised decision support systems, such as SANEX and WAWTTAR, is that the cost information is stored in the system. Data for a wider range of technology are contained in the systems than are shown in Table 1.

Table 2 shows actual costs in US$ for three technologies. These are based on 1995 costs, so inflation from 1995 should be taken into account when calculating costs for any particular year. It should be noted that these costs are average costs and are based on information from a limited number of countries.

Table 2: Costs per household of three technologies

	Relative Cost	US$ (1995)
Pit Latrine	0.28	160
Septic Tank	1	570
Conventional Sewerage	5.3	3020

The annual recurrent cost of the technologies is also indicated in Table 1. It is expressed as a percentage of the capital cost. Again it should be borne in mind that these are average recurrent to capital costs ratios. They should be used as guidance only, but they provide a useful indication of how much a particular technology will require to operate and maintain.

Table 1: Relative costs of wastewater management technologies

	Capital Cost Ratios	Annual recurrent cost (% of capital cost)
Bucket Latrine	0.19	150
Pit Latrine	0.28	5.1
VIP Latrine	0.55	2.6
Pour-Flush Latrine	0.53	2.7
Double-Vault Composting Latrine	0.97	0
Aquaprivy	0.53	8.9
Septic Tank	**1.00**	8.9
Seepage Pit	1.70	0
Drain Field	2.50	0
Conventional Sewerage	5.29	4.6
Simplified Sewerage	2.27	16
Settled Sewerage	1.11	4.6
Covered Stormwater Drains	1.38	16
Communal Septic Tank	0.20	10
Imhoff Tank	0.41	11
Primary Treatment	0.45	9.3
Waste Stabilisation Ponds	0.74	2.5
Activated Sludge Treatment	1.80	6.8
Nightsoil Treatment	0.52	25

Table notes: In order to peg the ratios, the following assumptions were made:

- The average household consists of five persons.
- One latrine serves one household, so does one aquaprivy. Figures for these systems include the superstructure.
- The pit emptying interval for latrines is five years.
- Unstable soil conditions require elaborate pit lining even for simple latrines.
- A septic tank is the conventional type with two compartments, receiving 200 L black- and greywater per person and day.
- Aquaprivies and septic tanks are desludged every three years.
- The soil absorption capacity is 20 L per square meter and day. Since authors of most cost figures give no respective information, this intermediate rate was selected.
- Off-site treatment figures were calculated for a medium size community of 10,000 persons, with each person discharging 200 L per day.

Source of costs data: Loetscher, T. (1999): Appropriate Sanitation in Developing Countries – The Development of a Computerised Decision Aid SANEX. Thesis. Advanced Wastewater Management Centre, The University of Queensland, Brisbane.

Appendix 3
maESTro and
UNEP contact information

The objective of the UNEP International Environmental Technology Centre (IETC) is to promote the adoption and use of Environmentally Sound Technologies (ESTs) in developing countries and countries with economies in transition. ESTs are designed to address urban environmental problems, such as sewage, air pollution, solid waste and noise, and to support the management of fresh water basins and the development of sustainable cities. In particular they encompass technologies that have potential for significantly improved environmental performance relative to other technologies. ESTs should also be compatible with nationally determined socio-economic, cultural and environmental priorities and development goals.

In order to help solve these problems and promote the adoption of ESTs, IETC has created and developed a searchable electronic EST-database called maESTro to provide information in a standardized, user-friendly format. maESTro consists of a comprehensive database providing up-to-date detailed information about ESTs and also provides a global directory of institutions and other sources of information. Information is regularly updated by IETC as well as by EST contributors, which include individual users as well as organizations and institutions. Through the internet-based maESTro, information about ESTs is available to all computer users who are linked to the world-wide web providing a global information network about EST's and there applications. For those without access to the internet, the database is also available in CD-ROM, floppy diskettes, and hard copy format at no cost.

maESTro is available at the URL: http://www.unep.or.jp/maestro

For further information, please address your queries and requests regarding maESTro to:

UNEP-DTIE-IETC Osaka Office
2-110 Ryokuchi Koen, Tsurumi-ku, Osaka City,
Osaka, 538-0036, Japan
Tel: (+81 775) 68 4580
Fax: (+81 775) 68 4587
e-mail: maestro@unep.or.jp

The United Nations Environment Programme can be contacted at the following locations:

Amadeo Buonajuti
Chief, Office of the Executive Director
United Nations Environment Programme
PO Box 30552
Nairobi
Kenya
Telephone: +254 2 62 1234
Fax: +254 2 22 6890 or 21 5787
Email: oedinfo@unep.org
Internet: http://www.unep.org/unep/oed/home.htm

Tore J. Brevik
Director/Spokesman
Communications and Public Information
UNEP
PO Box 30552
Nairobi
Kenya
Telephone: +254 2 623292
Fax: +254 2 623692 or 623927
Email: Tore.brevik@unep.org
Internet: http://www.unep.org/unep/cpi/Staff.html

Sarah Vinz
Special Assistant to Deputy Executive Director
United Nations Environment Programme
P.O. Box 30552
Nairobi
Kenya
Telephone: +254 2 623993
Fax: +254 2 623070
Email: sarah.vinz@unep.org

Maria de Amorim
Regional Director for Africa
UNEP/ROA
PO Box 30552
Nairobi
Kenya
Telephone: +254 2 62 4283 or 4284
Fax: +254 2 62 3928
Telex: 22068 UNEP KE
Cable: UNITERRA NAIROBI
Email: roainfo@unep.org
Internet: http://www.unep.org/regoffs/roa/home.htm

Nirmal Andrews
Regional Director and Representative for Asia and the Pacific
UNEP/ROAP
United Nations Building
Rajadamnern Nok Avenue
10th floor, B block
Bangkok 10200
Thailand
Telephone: +66 2 288 1870
Email: andrewsni@un.org
Internet: http://www.unep.org/unep/regoffs/roap/home.htm

Frits Schlingemann
Director
UNEP/ROE
Geneva Executive Centre
15 Chemin des Anèmones
1219 Chatelaine, Geneva
Switzerland
Telephone: +41 22 917 8111
Fax: +41 22 797 3420
Email: frits.schlingemann@unep.ch
Internet: http://www.unep.ch, http://www.unep.org/unep.regoffs/roe/home.htm

Richard Sànchez
Director
UNEP/ROLAC
Boulevard de los Virreyes No.155
Col. Lomas Virreyes
Apartado Postal 10793
11000 – Mexico, D.F.,
Mexico
Telephone: +52 5 202 7529 or 7493
Fax: +55 5 202 0950
Email: rsanchez@rolac.unep.mx
Internet: http://www.unep.org/unep/regoffs/rolac/home.htm

L. Brennan Van Dyke
Director
UNEP/RONA
1707 H St., N.W., Suite 300
Washington DC 20006
United States of America
Telephone: +1 202 785 0465
Fax: +1 202 785 2096 or 785 4871
Email: brennan.vandyke@rona.unep.org
Internet: http://www.unep.org/unep/regoffs/rona/home.htm

Habib N. El-Habr
Deputy Regional Director &
Officer-in-Charge
UNEP/ROWA
Villa No 2113 – Road No 2432
– Block 324 Juffair
PO Box 10880
Manama - Bahrain
Telephone: +973 826600
Fax: +973 825111 or 825110
Email: uneprowa@batelco.com.bh
Internet: http://www.unep.org/unep/regoffs/rowa/home.htm

Jacqueline Aloisi de Larderel
Director
UNEP-DTIE
39-43 quai André Citroën
75739 Paris, Cedex 15
France
Telephone: +33 1 44 37 14 50
Fax: +33 1 44 37 14 74
Email: unepie@unep.fr
Internet: http://www.unepie.org/

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UNICEF: School Sanitation and Hygiene Education (SSHE) together with its partners at global and country level is involved in the development of strategies and programmes to improve and promote sanitation and hygiene. Next to the promotion of sanitation and hygiene to ensure early child development (ECD), UNICEF is critically involved in the area of improved school sanitation and hygiene education. Below is a short list of resources related to SSHE. The Notes and News, is a news letter about the SSHE project and other SSHE issues, which will appear twice a year.
http://www.unicef.org/programme/wes/info/school.htm of UNICEF WES
http://www.unicef.org/programme/wes/pubs/glines/schsan.htm for the manual
http://www.irc.nl/sshe/ of IRC, with
http://www.irc.nl/sshe/nn/index.html for subscription to Notes and News
http://www.unicef.org/voy/meeting/urb/environ.html of Voices of Youth
http://www.unicef.org/teachers/ for information about life skills-based education click "Explore Ideas", then "The Teachers" (*)

UNICEF (1997) Towards Better Programming: A Sanitation Handbook Water**,** Environment and Sanitation Technical Guidelines Series - No. 3, UNICEF, New York.*http://www.unicef.org/programme/wes/pubs/glines/San_e.pdf*

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Glossary

Activated Carbon Activated carbon is produced by heating organic materials (e.g. coconut shells) in the absence of oxygen to a very high temperature (above 450 ^{o}C). The carbon that is produced has active surfaces; the latter can remove many pollutants from water.

Activated sludge Activated sludge is the assemblage of micro-organisms, dead and alive, together with adsorbed organic and inert materials present in aerated wastewater.

Activated sludge process In an activated sludge process settled wastewater is contacted with recirculated activated sludge in an aerated chamber. In this way a substantial amount of micro-organisms is kept in the treatment process to consume the organic materials in the wastewater. Excess sludge is removed after sedimenting the aerated mixture.

Aerobic With or in the presence of air (oxygen)

Aerobic lagoon Wastewater treatment lagoon that has a high dissolved oxygen level. This is usually a result of a combination of low organic waste input and sufficient oxygen transfer from the air, and occurs in the last few in a series of lagoons. See Lagoon.

Alkaninity A measure of the amount of acid that a given volume of water can absorb without substantially changing its pH.

Anaerobic Without air (oxygen)

Anaerobic digestion Decomposition of organic substances in the sludge by micro-organisms under anaerobic conditions.

Anaerobic lagoon Wastewater lagoon which has very little dissolved oxygen. This condition is the result of oxygen uptake by micro-organisms in the lagoon exceeding oxygen transfer from the air, and occurs in the first lagoon in a series of lagoons. See Lagoon.

Anoxic Without oxygen but with the presence of nitrate (chemically bound oxygen)

Aquaculture (wastewater fed) Rearing of fish in ponds relying on the nutrients (nitrogen and phosphorus) contained in wastewater. Guidelines for wastewater fed aquaculture should be followed to ensure protection of public health.

Attached growth system An attached growth system retains micro-organisms on the surfaces of solids (e.g. a bed of gravel or coarse sand) for the purpose of treating wastewater. As wastewater flows through the surfaces of the solids organic materials are consumed by the micro-organisms. See Trickling Filter.

Biochemical oxygen demand (BOD) A measure of the strength or concentration of wastewater. This is so because micro-organisms consume the organic substances in the wastewater for energy and growth. In the process of microbial respiration dissolved oxygen is taken up from the water by the micro-organisms. Because the oxygen uptake is measured over a period of 5 days, it is also denoted as BOD_5

Biofilter A biofilter is used for the treatment of wastewater by passing the wastewater through a bed of gravel, coarse sand or other solid surfaces. Organic substances are removed by micro-organisms attached to the solids surfaces (See Attached Growth system).

Biofilter for odour A biofilter used for the treatment of odorous gases consists of a bed of mature compost. As the odorous gas passes through the moist compost bed the odorous substances are adsorbed to the compost and degraded by compost micro-organisms.

Biogas Biogas is the gases that are produced from the anaerobic decomposition of organic materials (e.g. sewage sludge). The gases are mainly methane and carbondioxide, and hence have energy value from its methane content.

Biogeochemical cycles Natural cycles of elements which constitute living materials of plants and animals. These elements (e.g. carbon, nitrogen, phosphorus) occur in various forms in the living organisms, in the dead organisms, in the soil and atmosphere and when they are taken up again by organisms.

Biological filter See Trickling Filter

Biological nutrient removal (BNR) Nutrients in wastewater (nitrogen and phosphorus) can be removed by the use of specific groups of micro-organisms by providing suitable conditions for their growth. Systems that are designed and operated to achieve this purpose are called BNR systems.

Biosolids The term used for sludge removed from the treatment of sewage that has undergone processing and with the intention of reusing the sludge.

Blackwater Waste from the toilet. See Greywater.

Bucket latrine Latrine where faeces and urine are collected in a bucket. See Night Soil.

Carbon cycle See Biogeochemical cycle.

Catchment (basin) Area of land from which stormwater run-off flows to a common stream or river.

Central(ised) systems Centralised systems are systems where wastewater and/or stormwater are collected from individual houses and brought to a central treatment plant. A system of pipes (sewer) is used for this purpose. Gravity is relied upon for flow, but pumping may be required.

Centrifuge (sludge) Mechanical equipment used to remove moisture from sludge by giving the sludge a rotating motion in a drum forcing the mixture of water and solids towards the cylindrical surface of the drum where a filter medium is placed. Water passes through while the solids are retained on the filter mediu.m.

Chamber soakway A chamber where stormwater run-off is directed to. Water percolates through the sides and bottom of the chamber into the surrounding soil to groundwater.

Chlorination The use of chlorine for the purpose of disinfection of water. Chlorine is available in the form of chlorine gas or solid (calcium hypochlorite, e.g. powder or tablet) or liquid (sodium hypochlorite).

Clarifier A clarifier separates solids from wastewater by settling the solids out in a settling pond or tank, and in this way the wastewater is clarified.

Coliforms Bacteria which are abundant in the blood of warm blooded animals

	including people. They are used as an indicator of faecal contamination of water.
Combined sewer	Combined sewer carries both wastewater and stormwater. Separate sewers collect only wastewater or stromwater.
Combined sewer overflow (CSO)	Combined sewer (see above) invariably results in an overflow during heavy rain storm. This overflow is the volume that exceeds the capacity of the treatment plant and is termed combined sewer overflow.
Composting	Composting is the process that converts organic materials into humus. This process is carried out by micro-organisms under aerobic conditions.
Composting toilet	A composting toilet collects human excreta in an aerated chamber for the purpose of producing humus by composting. Air is drawn from the toilet chamber into the collection chamber and out through a vent, thus odour is controlled.
Conditioning (sludge)	Sludge may need to be conditioned to assist the process to reduce its moisture. This is usually done by adding chemicals that help coagulate or flocculate the particles in the sludge.
Condominium sewerage	Pipes which collect wastewater in a condominium sewer pass through neighbouring properties. This saves pipes compared to conventional sewer where pipes from each property are connected to mains running in front of the properties. See Simplified Sewerage.
Constructed wetlands	See Wetlands
Conventional sewerage	In conventional sewerage pipes are laid relatively deep in the ground to prevent interference from traffic, and allowance is made for self-cleansing flow in the pipes on a daily basis. As a result pipes are larger in size and are laid deeper compared to shallow sewerage. Costs are correspondingly higher.
Cross-cutting issues	Cross-cutting issues in the implementation of environmentally sound technology refers to the broader issues of planning, involvement of the community, methods for cost-recovery for capital cost and for operating cost, and other social and political factors to ensure successful and long term sustainability of the technology.
Dechlorination	The removal of excess chlorine once the objective of chlorination (disinfection) has been achieved.
Denitrifiers	Bacteria which carry out the denitrification process.
Denitrification	The conversion of nitrate into nitrogen gas. This process is carried out by denitrifiers and requires an organic carbon source and anaerobic conditions.
Digestion (aerobic, anaerobic)	Digestion is the process of biodegradation of organic materials by micro-organisms. It can take place under aerobic conditions (in the presence of air) or anaerobic conditions (in the absence of air).
Disinfection	The removal of pathogens. This can be done in a number of ways (e.g. boiling water, ultra-violet radiation, chlorination).
Dissolved air flotation (DAF)	The process of removing suspended solids (such as oils and grease particles) by floating them using very small air bubbles and skimming them. Pressurised air is dissolved in the water, and when the pressure is reduced to atmospheric very small bubbles are produced.
Dissolved oxygen	Dissolved oxygen is the oxygen that is dissolved in water. At an

(DO) ambient temperature of 20 ^{o}C the amount is about 9 mg/L (parts per million). The small amount of oxygen that can be dissolved in water limits its availability to aquatic organisms, and can be readily depleted by wastewater. See Biochemical Oxygen Demand.

Drying bed (sludge) A bed of sand on which wet sludge is placed for drying. Moisture is removed by evaporation and percolation through the sand bed. Excess water is removed from the base of the bed for further treatment.

Environmentally sensitive zones Environmentally sensitive zones refer to water bodies, such as rivers, lakes and seas, that are sensitive to addition of nutrients (nitrogen and phosphorus). See Eutrophication.

Eutrophication Eutrophication refers to the process or conditions of a water body that receives and contains excessive amounts of nutrients. These conditions result in algal bloom. Toxins may be produced by some algae. The decay of the algae can result in depletion of oxygen from the water body.

Evapotranspirati on In wastewater treatment it refers to the removal of the water by use of plants. The plants act a biological pump by absorbing moisture through their roots and transpiring it to the atmosphere. Water can distributed in a trench filled with gravel and topped with sand or soil (Evapotranspiration trench) or when the water table is high, into a bed of sand above ground (Evapotranspiration bed).

Facultative lagoon Wastewater treatment lagoon which contains a high level of oxygen during the day but a low level at night. Algae in the lagoon produce the oxygen during sunlight hours by photosynthesis, and taking carbon dioxide produced by the respiration of bacteria consuming the organic waste. See Lagoon.

Filter drains Permeable materials located below ground to store stormwater run-off. Run-off flows to the storage area via a permeable surface.

Filter press (sludge) Pressure filter consisting of plates and frame. Sludge slurry is pumped under pressure onto a filter medium placed on the plates. Solids are retained on the filter and water passes through, thus dewatering the sludge.

Filter strips (stormwater) Vegetated surface that allows stormwater run-off to flow evenly to collection areas while at the same time filters solids out of the water.

Garburator Garburator is usually installed beneath a kitchen sink to shred kitchen waste and dispose it with wastewater. Treatment of the wastewater involves removing the kitchen waste from the wastewater, so it may not be considered as a desirable method for disposing of kitchen waste.

Grass filtration See Overland Flow

Grease trap Grease trap is a device to remove grease from wastewater, so that the grease does not interfere with downstream treatment of the wastewater (e.g. blockage).

Greywater Wastewater from bathroom, laundry and kitchen. See Blackwater.

Grit removal The removal of solids that settle relatively quickly from wastewater (e.g. sand particles). This is usually carried out in a settling time with a short residence time.

Heavy metals Metals such as copper, zinc, cadmium, chromium and lead. In wastewater treatment they are usually concentrated in the sludge.

Human excreta Faeces and urine.

Incinerating toilet Incinerating toilet refers to a dry toilet where the solids are combusted. Used usually in isolated area (e.g. permanent snow).

Incineration (sludge) Combustion of sludge. Usually in a multiple hearth or fluidised bed furnace. It is relatively costly and may produce air pollution.

Infiltration trench (stormwater) A trench into which stormwater run-off is directed and is allowed to infiltrate to the groundwater. See also Chamber soakway.

Integrated waste management Integration of the management of solid waste, wastewater and stromwater to achieve protection of public health and the environment. The integration can also be seen in a wider context with hygiene promotion, community consultation and participation and matters associated with the above.

Lagoon Lagoons or ponds are natural or engineered excavations in the ground and used to treat wastewater and stormwater. Settling of solids and degradation of organic materials by micro-organisms take place in the lagoons. They are therefore also called stabilisation lagoons or waste stabilisation lagoons.

Landfill(ing) A landfill is usually an excavation in the ground where waste is buried, and landfilling refers to the method of waste disposal by burying the waste in the ground.

Leach pit or drain Pit or drain into which the overflow from a septic tank is directed. Water leaches (infiltrates) into the ground. The soil surrounding the pit or drain must be permeable and not close to the water table.

Lime stabilisation Lime stabilisation refers to the addition of lime (calcium oxide) to waste (e.g.sludge). In this way the pH of the sludge is increased usually to above 11 and hence bacteria (including pathogens) are killed.

Mesophilic The conditions of composting where the temperature initially rises, but still below 40 ^{o}C. See Thermophilic.

Membrane filtration Membrane filtration uses a membrane that passes water and some salts. In this way the water passing through (the permeate) contains less salt and bacteria. A high pressure is required to push the water through the membrane.

Micro-organisms Micro-organisms in wastewater treatment include bacteria, fungi, protozoa and crustaceans which convert organic wastes to more stable less polluting substances

Natural cycles See Biogeochemical cycles

Natural purification Processes occurring in nature which remove pollutants or convert them or render them less harmful to the environment. Examples are the removal of suspended solids in quiescent stretches of a river and removal of organic wastes through consumption by naturally occurring bacteria.

Night soil Night soil refers to human excreta that is stored in buckets and collected nightly for reuse, treatment or disposal.

Nitrification Conversion of ammonium in wastewater to nitrate. This process is

	carried out by nitrifiers under aerobic conditions.
Nitrifiers	Bacteria carrying out the nitrification process.
Nitrogen	An essential and important plant nutrient. It occurs in several forms: organic nitrogen, ammonia, nitrite and nitrate.
Nitrogen cycle	See Biogeochemical cycles.
Nutrients	Nutrients refer to the elements that are required by plants and animals, although nitrogen and phosphorus are generally the major nutrients of concern in wastewater. See Eutrophication and Environmentally sensitive zones.
On-site systems	Waste treatment systems that are located where the waste is produced. See Centralised systems.
Overhung latrine	Latrine located above water (river or coastal water) and human excreta drops directly into the water.
Overland flow	Overland flow refers to the treatment of wastewater by passing it through land. Purification of the wastewater takes place as it flows through the soil. Grasses growing on the soil transpire part of the water and take up nutrients.
Oxidation ditch	Channel in the form of a ring for the treatment of wastewater. The wastewater is moved along the channel to assist with aeration. Treatment processes are similar to what takes place in a lagoon.
Pathogens	Bacteria, viruses, protozoa and helminths which cause illnesses.
pH	pH indicates the degree of acidity or alkalinity of water. Neutral pH is seven, whereas a value below 7 indicates acidic conditions and above 7 alkaline conditions. Living organisms usually tolerate a pH of between 6 and 9.
Pit privy	Pit privy or latrine is a latrine built on top of a dug pit. Human excreta is deposited into the pit. When the pit is full the content is dug up, or the latrine relocated and the pit covered with soil.
Phosphorus	Phosphorus is an essential and important plant nutrient. It occurs as organic phosphorus and phosphate.
Pond	See Lagoon
Pour flush toilet	A pour flush toilet has a water seal and is flushed by pouring 2 to 3 L of water into the pan.
Primary sludge	Sludge produced from primary treatment of wastewater.
Primary treatment	The treatment of wastewater by screening and sedimentation to remove solids.
Pyrolysis (sludge)	Heating of sludge to a very high temperature in the absence of oxygen or in the presence of controlled small amounts of oxygen. Under these conditions the sludge is converted into water, gas, oil and char.
Rapid rate land application	See Soil Aquifer Treatment
Rainfall run-off	Water from rainfall that flows over surfaces.
Retention basin	Basin or pond used to store stormwater run-off. Flooding potential is therefore reduced. Settling of solids and infiltration of water into the ground occur during retention.
Return activated sludge	Activated sludge that is returned to the aeration tank of an activated sludge process to assist with treatment of wastewater. See Activated Sludge.

Rotating Biological Contactor (RBC)	A rotating biological contactor is used to treat wastewater and consists of rotating disks that are partly immersed in the wastewater. In this way the wastewater is entrained in the rotating disks and aerated, and aerobic bacteria consume organic wastes.
Run-off	See Rainfall run-off.
Sand filtration	The operation of passing water through a bed of sand to remove suspended solids from the water.
Secondary treatment	Secondary treatment refers to the treatment of wastewater after primary treatment. Aeration is introduced to supply oxygen to the bacteria consuming the organic materials in the wastewater. See Activated sludge and Trickling Filter.
Sedimentation	The removal of suspended solids by slowing the velocity of flow of the wastewater. In this way solids settle to the bottom of the sedimentation tank or pond.
Septage	The sludge that accumulates in a septic tank.
Septic tank	On-site tank for the storage of solids in wastewater. Regular emptying of the accumulated solids is required so that it can function properly. See Septage, Leach drain/ pit and STEP.
Septic tank effluent pumping (STEP)	STEP refers to the conveyance of the overflow from septic tanks by pumping it to a central collection point. Pumping overcomes the need to have large diameter pipes which rely on gravity flow.
Sequencing batch reactors (SBR)	An Activated Sludge Process that is operated batchwise (rather than with a continuous flow of wastewater). Each step of the Activated Sludge Process is done in sequence. Two tanks in parallel are required to deal with continuous flow of wastewater.
Settled sewerage	Sewerage that conveys wastewater that has undergone settling to remove suspended solids.
Sewage	Sewage is wastewater produced from human activities in a household, and consists of human excreta, kitchen waste, bathing water and washing water. See Sewerage.
Sewerage	Sewerage refers to the pipes and drains which convey sewage. A sewerage system includes the pumps that may be required if gradient for gravity flow is not sufficient. Sewerage usually also conveys stormwater and industrial wastewater. See Sewage.
Sewer mining	Withdrawal of wastewater from a sewer pipe for reuse purposes. Treatment of the wastewater is required to meet the requirement of reuse.
Shallow sewerage	See Simplified Sewerage
Simplified sewerage	In simplified sewerage pipes are laid relatively shallow in the ground when traffic above is light. Design horizon is shorter compared to conventional sewerage. As a result pipes are smaller in size and are laid shallower compared to conventional sewerage. Costs are correspondingly lower.
Sludge (sewage sludge)	Sludge is the solids that are produced from human excreta or from the treatment of wastewater.
Solids	Solids refer to materials which are in solid form. They are generally in the solid phase, but may dissolve in water (e.g. salts and sugar). Hence the reference to Dissolved Solids or Total Dissolved Solids. See Suspended Solids.
Solids free	See Settled Sewerage

sewerage	
Stabilisation	Stabilisation refers to the decomposition of organic materials by micro-organisms. The organic materials are converted into more stable less biodegradable materials and therefore do not produce as much odour and less attractive to insects.
Stormwater	Stormwater is water which results from storm and rainfall generally. See run-off.
Suspended solids (SS)	Suspended solids are solid particulate matter contained in water. They are generally removed by settling, but for light particulates by floating. See Dissolved Air Flotation.
Suspended growth system	A suspended growth system retains micro-organisms in a wastewater treatment system in the form of flocs suspended in the wastewater. An activated sludge process is an example of a suspended growth system. See Attached Growth System.
Swales (stormwater)	Long shallow channels which intercept stormwater run-off (e.g. from a Filter strip). They act to store the water temporarily and allow it to infiltrate to the ground.
Tertiary treatment	The treatment of wastewater beyond secondary treatment, but may be used to refer specifically to the removal the nutrients nitrogen and phosphorus. See Secondary Treatment.
Thermophilic	The conditions of composting where the temperature is above 45 ^{o}C. Heat is generated from the activities of micro-organsims consuming the organic materials in the compost. Oxygen requirement is highest in this active period. Can be taken advantage for compot sterilisation purposes.
Thickening (sludge)	The process of removal of water/moisture from the sludge. This is usually done by allowing the solids in the sludge to settle and decanting the excess water.
Toilets	Facilities for urination and defecation including the housing required for such facilities.
Total Dissolved Solids (TDS)	See Solids
Total Suspended Solids (TSS)	See Suspended Solids
Trickling filter	A trickling filter is an example of an Attached Growth System. Wastewater is allowed to flow through the filter bed. Organic materials in the wastewater are consumed by the micro-organisms attached to the surfaces of the filter bed. See Attached Growth Sytem.
Ultraviolet disinfection	Ultraviolet disinfection utilised ultraviolet radiation (e.g. from the sun) to achieve disinfection. See Disinfection.
Upflow Anaerobic Sludge Blanket (UASB)	An anaerobic process for the treatment of wastewater (usually with a high BOD). Wastewater is passed through a tank from below through a bed of sludge containing the micro-organism which consume the organic wastes.
Vault latrine	A latrine where human excreta is stored in a vault, which is emptied regularly of the sludge.
Waste	A waste management method which considers prevention of waste as

management hierarchy	the highest priority, followed by waste minimisation, recycling, reuse and treatment prior to disposal. The latter is considered to be of the lowest priority.
Wastewater	Wastewater refers to water that has been used in households and also in other activities, e.g. industry producing industrial wastewater. See Sewage.
Waste stabilisation pond	See Lagoon.
Wetlands	Water bodies that are generally shallow and may not have permanent water. Artificial wetlands (constructed wetlands) are wetlands that have been created to receive stormwater, or treat wastewater.
Waste Activated Sludge (WAS)	Activated sludge that is in excess of the requirement of an activated sludge process and is wasted from the process. See Activated Sludge and Activated Sludge Process.
Water cycle	The natural cycling of water in the environment, which include evaporation of water from the oceans, seas, rivers and lakes, the condensation of the evaporated moisture as rainfall, the resulting rainfall run-off, water infiltration to the groundwater, uptake by plants, and water flowing in rivers to the seas and oceans.