

Guidelines on Sewage Treatment and Disposal for the ROPME Region, including Guidance for Submarine Outfall Structures



Regional Organization for the Protection of the Marine Environment

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Foreword

Of the many critical approaches to protecting the marine environment, judicious management of effluents from land-based activities is an important aspect of high priority. In the ROPME Sea Area (RSA), the closed nature of the marine environment poses natural restriction to circulation, which in turn simulates an amplified effect of pollutants on the biota by longer time of residence. Thus, it is imperative that we evolve context specific guidelines for the discharge of land-based effluents into the coastal waters and develop appropriate methods of waste treatment that would minimize pollution and environmental degradation. ROPME is constantly reminded of the grim scenarios that may emerge if the discharges from land-based activities into the RSA are not properly regulated. This has been the background to the efforts made by ROPME in the recent times to collect and collate the essential information on LBA for the management of discharges into the coastal waters as a first step towards mitigation of emerging problems. This document on guidelines epitomizes our collective efforts.

ROPME received generous support from UNEP/GPA in this important endeavour and a Memorandum of Understanding between our institutions guided the activities leading to the document. Under the provisions of the Memorandum, ROPME enlisted the services of a project consultant, Mr. Dimitrios Tsotsos, who completed the difficult task of compiling the text of the draft 'Guidelines' within a short time. A meeting was held in Doha, Qatar during late June 2005 to discuss in detail the draft guidelines and I acknowledge the guidance provided by the representatives of Member States and the inclusions they suggested. With all these, I sincerely hope that the serious and genuine attempt on behalf of ROPME and UNEP/GPA would be considered a landmark and a new beginning on the path of environmental protection in the Region.

ROPME hopes to receive constructive feedback from Member States and other concerned entities on the document, enabling timely revision and further development of the guidelines in the efforts towards mitigating the avoidable negative effects of land-based activities.



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Executive Secretary, ROPME

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1 INTRODUCTION

1.1 Scope of the document

The scope of this document is to provide comprehensive and practical information to its users about important aspects concerning planning and management of options for sewage collection, treatment and disposal into coastal waters. Under the term **sewage** what is meant is **municipal/domestic/urban wastewater** discharged from households, commercial undertakings, small industries connected with the sewer system and hotels.

The main objective is to review and evaluate existing information concerning sewage management, in particular the information contained in the documentation provided by international institutions (UNEP, EU, World Bank, etc.) and to adapt it to the requirements of the Protocol for the Protection of the Marine Environment against Pollution from Land Based Sources for the ROPME (Regional Organization for the Protection of the Marine Environment) Sea Area. (Appendix I). References to this documentation will be made, so that interested readers can find the relevant chapters and extract more details. Scientific publications of relevance will be brought into focus, in order to consider and verify data collected elsewhere. In this context it must be pointed out that this document is not a technical handbook for the execution of engineering solutions i.e. design, construction and operation of wastewater management facilities (treatment plants, sewers, submarine outfalls): it simply intends to help finding those planning options that are needed for the proper wastewater management. It also does not deal with industrial effluents, which is addressed in the Guidelines for the Management of Industrial Wastewater for the ROPME Region.

These guidelines deal with urban wastewaters and effluents from urban wastewater treatment plants for domestic and pre-treated industrial wastes. They do not cover effluent discharged directly into the environment from sources such as:

- industries;
- storm water drains;
- overflows;
- septic tanks, etc.

In these guidelines, it is assumed that the industrial effluents connected with urban wastewater collecting system are pre-treated at the industrial treatment plant in accordance with the local and national guidelines for industrial effluents. The general rule is that the industrial effluents, prior to being discharged into the urban wastewater collecting system, should have quality equal to or better than the typical untreated domestic wastewater, in order to be transported to and treated at the urban wastewater treatment plant.

1.2 Target groups

The target groups to mainly use these guidelines are:

- **Decision makers/planners** who will set up the framework of their policies on the basis of a solid knowledge of the various issues relevant to municipal wastewater management.
- **Regional/local authorities** being responsible to take decisions on local level about the optimum wastewater management solutions e.g. common treatment plants for small communities, acceptance of pre-treated industrial effluent discharges into the sewer system, etc. and involved in the preparation of coastal management plans.
- **Inspectors** of treatment facilities who will be helped for better monitoring of the relevant installations.

1.3 Structure of the document

This document will allow the readers/target groups of these guidelines to understand the main “questions” arising when municipal wastewater management systems have to be planned and constructed and find the “pathways” where and how to search for the necessary detailed information for the practical implementation of the various alternative options. In doing so, an integrated approach for effective wastewater management has to be formulated and these guidelines briefly describe all elements needed for planning of relevant solutions, which, besides the central issue of selecting the appropriate technical systems, should give an insight into the whole cycle of wastewater generation and its final disposal into water recipients.

In this context, **the assessment of the existing conditions of the marine environment** is essential to understand how the water recipient of treated effluents functions: municipal wastewater discharges are of particular importance due to their impacts. Wastewater improperly discharged to freshwater and coastal environment presents a variety of concerns, such as: (a) pathogens that may result in human health problems, (b) increase in suspended solids, (c) significant nutrient inputs, and (d) higher levels of biochemical oxygen demand (BOD). These aspects are presented in **Chapter 2**. The assessment of the **adverse effects** of municipal wastewater discharge into the marine environment and an inventory and estimation of **pollution loads** entering the sea and the prescription of **effluent standards** is essential bearing in mind the aspects described in Chapter 2: the carrying capacity of the marine environment has certain limits for effluent acceptance, in order to keep the desirable ambient water quality (**Chapter 3**).

In order to meet the set effluent standards, the selection and design of the appropriate **wastewater collection, treatment and disposal systems** are to be elaborated taking into consideration the existing conditions and the future development plans in the area concerned (**Chapter 4**). **The environmental impacts** caused by the wastewater management facilities have also to be assessed. An analysis of the main issues to be

taken into consideration when preparing environmental impact assessment (EIA) for those facilities is presented in **Chapter 5**. The organizational aspects together with the necessary **institutional arrangements** for effluent monitoring are analyzed in **Chapter 6**. The use of economic instruments and of cost recovery mechanisms is presented in **Chapter 7**. Finally, a set of conclusions and recommendations summarizes the main issues to be considered for successful planning of waste management systems (**Chapter 8**).

2 THE MARINE ENVIRONMENT

2.1 Water uses

Coastal waters serve a wide variety of human uses, which create high local benefits such as recreational activities, fishing, aquaculture, etc. These uses are directly depending on the quality and nature of the biological, chemical and physical systems present in the marine environment. Seawaters are becoming increasingly chemically and microbiologically contaminated and may cause severe health implications for those, who come in contact with (i.e. bathing) or exploit (i.e. fishing, aquaculture) them. Monitoring of water quality and the conducting of epidemiological surveys can help assessing the potential health risks.

An indicative and non-exhaustive list of these uses is summarized below:

- commercial shipping
- shoreline development
 - for residence
 - for industrial development
 - for recreation
- recreation and aesthetics
 - boating
 - swimming
 - fishing
 - enjoyment
- mining
 - oil and gas
 - minerals
- biological harvesting
 - food (aquaculture)
- energy (i.e. electricity) generation (usage of cooling water)
- water extraction (i.e. desalination)
- military purposes
- preservation of
 - species
 - ecosystems
 - productivity
- waste disposal
 - municipal waste
 - industrial waste

The required quality for the undisturbed use of seawater is mainly affected when pollutants enter the marine ecosystem. The discharge of the pollutants to the system might:

- reduce the input of solar energy into the ecosystem
- increase the input of organic matter and nutrients, which stimulate the growth of undesirable species

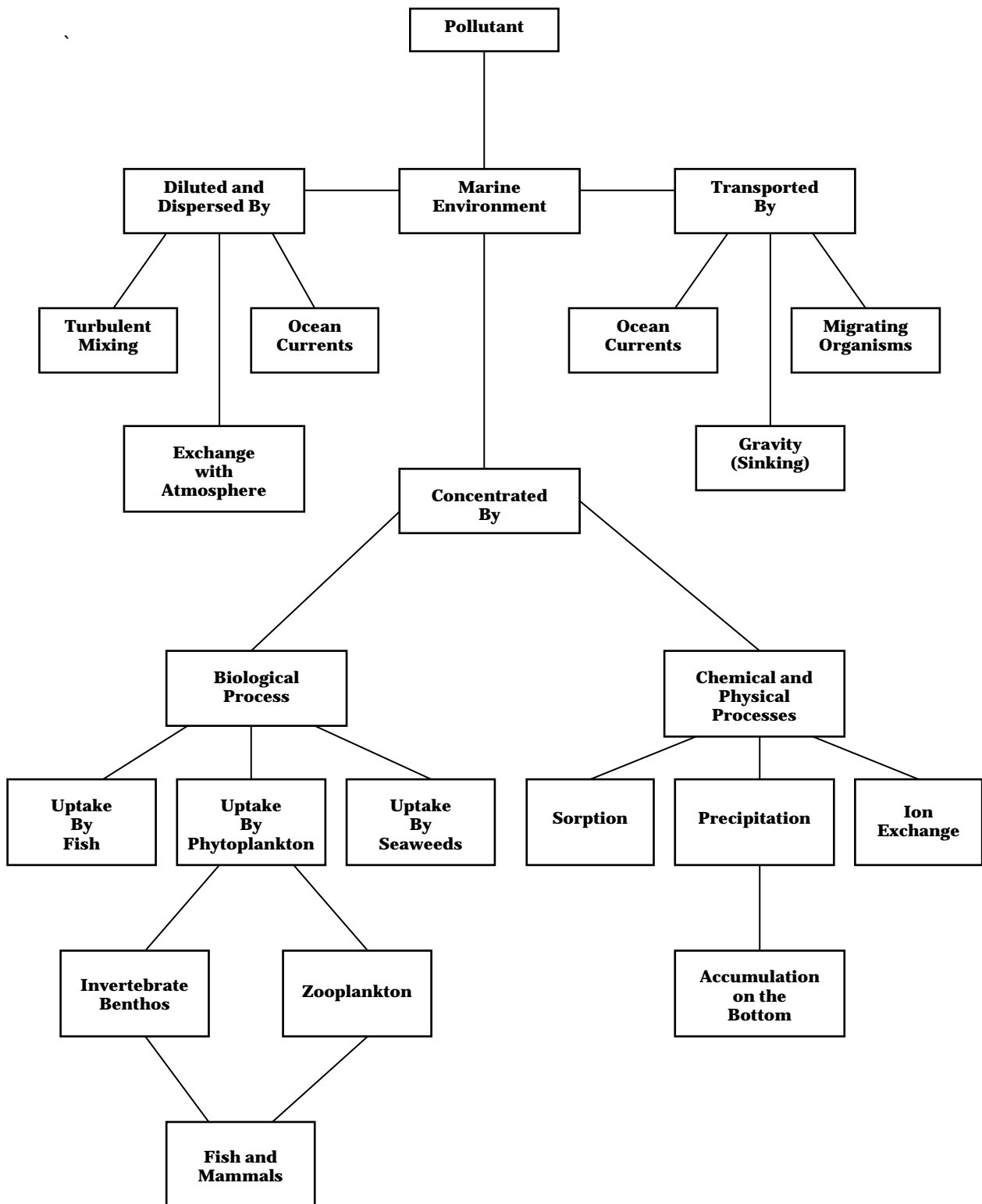
- reduce the availability of nutrients by increased sedimentation
- cause physical extreme conditions for some organisms e.g. by the addition of heat
- eliminate species by adding toxic materials
- reduce species diversity
- decrease biomass
- destruct the habitats of organisms
- reduce the stability of ecosystems
- replace desirable species with less useful ones
- introduce pathogens and parasites
- produce aesthetically unattractive conditions.

The drawing up of the water use area boundaries is a multidisciplinary activity involving biologists, chemists, environmentalists, the general public, politicians and other interested parties. These areas are generally defined by development planning processes of the regions.

Definition of the water use in the area concerned is one of the first steps in the wastewater management planning after considering the environmental conditions.

A schematic diagram showing the pathways and impacts of a pollutant entering the marine ecosystems is presented in Figure 2.1.

Figure 2.1 Processes determining the fate of a pollutant reaching the marine environment



Source: Code of practice for environmentally sound management of liquid waste discharge in the Mediterranean Sea, UNEP/MAP – PAP/RAC, 1990

2.2 Assessment of sea water conditions

2.2.1 Introduction

The assessment of the prevailing conditions in the sea water will allow the proper determination of the circumstances in the sea area, which has to be protected in its uses. Additionally, it will provide the planners for wastewater management facilities with all necessary information for placing the submarine outfalls. In doing so, extensive studies have to be elaborated for the sea areas concerned, which will form the basis for the plan to set the outfalls.

The basic data required for a preliminary evaluation of the pollution implications to the marine environment and to assess the potential of a sea area can be related to a) physical oceanography and meteorology b) biological and chemical conditions c) sea bed conditions (geomorphology of the coastal zone) d) existing waste discharges and e) physical characteristics of the coastline (e.g. freshwater discharges). This information must be collected from on-site observations and relevant research studies. In the following paragraphs some explanations related to the items need to be considered when conducting the required studies are summarized, so that a glance on this vast research topic can be made.

2.2.2 Physical oceanography and meteorology

In the coastal zone, physical oceanographic parameters are influenced by the form of the coastline and its topography and from the meteorological/climatic conditions. As a matter of fact, pollutants from one area can be carried along shore to other coastal areas and affect the relevant water uses due to the prevailing oceanographic and meteorological conditions.

The necessary special studies are e.g. current measurement programs, wave observations, in-situ dispersion experiments, etc. These studies in general should be:

- tailored to the specific area (bay, open coast, estuary) and its needs
- coordinated with biological, chemical studies
- adjusted to existing research potential of the country
- based on measurements (existing or to be produced)

The various types of **currents** (density currents, currents caused by winds/tide, currents caused by rivers flowing in the coastal area) and the **density** of seawater play an important role in this investigation and have to be separately studied, since factors heavily influence the physical destination of effluents discharged into the sea.

Concerning marine meteorology, the following conditions should be investigated:

- wind direction, intensity and duration
 - precipitation
 - cloud coverage
 - state of the sea
 - visibility
-

The winds strongly influence the surface currents, whereas heavy precipitation increases the land drainage and water flow significantly compared to dry weather conditions.

2.2.3 Marine biology

The investigation of the biological conditions in a sea zone starts with:

- chemical water analysis
- selected bioassay of organisms
- detection of any morphological abnormalities in fish population
- changes in population dynamics

The investigation should aim at the survey of benthic communities, the assessment of physiological and biochemical indices of widespread species. This investigation will show any alterations in the biological conditions by any effluent discharge or other adverse effect and will help to determine the sensitivity and suitability of the sea area concerned to accept wastewater discharges.

There are some **species**, which are considered by biologists to be useful indicators of environmental quality by virtue of their dominance or significance (relative abundance) in the biological community in the sea area concerned. The nature of these species depends on local sea conditions and cannot be prescribed in advance. Local observations of the sea community will give an insight of the abundance of any of these species and, therefore, an indication of the relevant sea water quality.

2.2.4 Geomorphology of the coastal zone

The sea bed morphology is of concern because of its influence upon marine biota, seawater circulation and sedimentation in the coastal regions: the capacity of diluting a contaminant is normally lower in broad shelf areas than in those characterized by steep offshore slopes, which allow the larger-scale oceanic circulation.

Surveys might be required to collect information about channel depths, shelf canyons, reefs as well as to identify any seismic/sub-bottom profile. The assessment of data concerning marine sediments (including their transport and deposition) and the suspended sedimentary load of rivers discharging their waters in coastal regions is also important for understanding of the prevailing conditions in an area where installations will be constructed and outfalls be placed.

2.2.5 Microbiological and chemical observations

In order to assess the existing seawater quality, a number of analyses have to be performed for the determination of the level of the critical microbiological and chemical parameters, which define acceptable quality levels. Some of the most important parameters are:

microbiological parameters

- faecal coliforms
- enterococci
- E.coli
- total coliforms

chemical parameters (in sea water)

- total N
- total P
- dissolved oxygen
- pH
- heavy metals (Cd, Pb, Zn, Cu, Ni, organotin compounds, etc.)
- temperature
- salinity

chemical parameters (in organisms)

- metals
- organic compounds

chemical parameters (in sediments)

- heavy metals
- organotin compounds
- organic compounds

2.3 Water quality

2.3.1 Assimilative capacity of the marine environment

The term **assimilative capacity** can also be expressed as **environmental capacity** of the receiving water body and describes the extent of the water's ability to accommodate waste without adverse quality effects. This capacity will vary with the characteristics of each sea area and with the type and number of effluent discharges. In cases where wastewaters are added to waters at rates that exceed their capacity to recover, then the water quality deteriorates rapidly.

The average concentration of a given pollutant continuously added to a water body will tend to approach a steady state in the system. This concentration is determined by the rate of addition of the pollutant, the rate of its dilution and of its decomposition by biological, chemical, physical and geological processes.

In order to assess the assimilative capacity of a seawater area, which is a form of environmental modeling, a set of activities should be carried out for obtaining the necessary data. The following activities are proposed:

1. make local inventories of the various types and quantities of wastes discharged in the area
 2. differentiate between natural and human-made waste quantities and between point and non-point sources
 3. analyze transport and transformation processes to understand the functioning of waters as waste recipients
 4. determine the chemical, physical and biological information needed for the evaluation of the assimilative capacity
 5. develop criteria for determining the acceptability of wastewaters for their disposal
 6. define the future water uses in the area.
-

2.3.2 Seawater quality criteria

Water quality criteria are designed to provide long term protection and provide a basis for the definition of **effluent standards** but they should not become effluent standards: water quality criteria usually specify concentrations of water constituents, which, if not exceeded, guarantee the water quality prescribed by its uses. Such criteria derive from scientific facts and on-site observations. It is evident that schemes for wastewater disposal into the marine environment should be designed primarily taking into account the beneficial uses to be protected in the area affected by the discharge. Therefore, water quality criteria derived from these uses are the principal parameters in the computations concerning the efficiency of a wastewater disposal system (i.e. submarine outfall).

In order to be used in the design and calculation of a submarine outfall, water quality criteria need to fulfill the following basic characteristics:

- The criteria have to be expressed in terms of parameters and values, which should be taken into consideration by the design procedure (formulation of effluent standards).
- Criteria and parameters should be relevant to the beneficial use that the submarine outfall has to protect. They have to be associated with sanitary and ecological consequences, either through a direct cause-effect relationship or through a clearly stated statistical relationship.
- Criteria should be attainable by normal technical procedures and should take into account the natural base-line concentrations in the relevant waters.
- Although, for purposes of the computation of submarine outfalls, only average values will be used, in order to take into account the natural variability and changes of environmental parameters, water quality criteria should be defined in a statistical form.

Examples of seawater quality criteria are listed in Table 2.1.

Table 2.1 Recommended seawater (bathing water) quality criteria

Parameter	Unit	Percentage		Remarks
		80%	95%	
A. Bacteriological				
1. Faecal Coliforms	Nr/100 ml	100	2000	bathing area
2. Faecal Streptococci	Nr/100 ml	100	400	
		50%	90%	
B. Physical				
1. Color	mg Pt-Col/l	10	30	+
2. Suspended solids	mg/l	1.3NV	1.5NV	++
C. Chemical				
1. Dissolved oxygen	mg/l	6	5	surface
2. Nitrogen ammonia	mg N/l	0.05	0.12	
3. Dissolved orthophosphate	mg P/l	0.02	0.05	

+ to be observed at the plume surfacing point

++ NV = Normal value in the area before the discharge

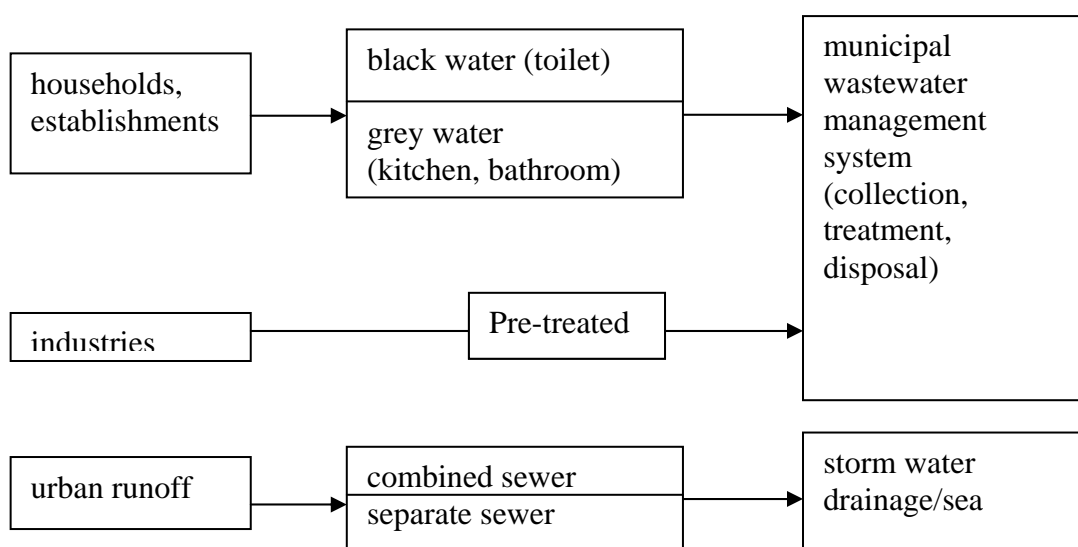
Source: Guidelines for submarine outfall structures for Mediterranean small and medium-sized coastal communities, UNEP/MAP-WHO, Technical Reports Series 112, 1996

3 POLLUTION SOURCES

3.1 Point sources

3.1.1 Municipal wastewater/sewage

Municipal wastewaters/sewage are the wastewaters coming out from urban sources (houses, tourist units, schools, etc.) as well as industrial effluents pre-treated to the level of raw municipal wastewaters. Their composition is predictable, since it depends on human water consumption and habits. Areas with scarce water resources tend to have lower wastewater generation than those with abundant resources, however, the composition is almost the same all over the various parts of the world. The values vary with the type of wastewater collecting system used and wastewater input. Concentrations are higher in separate systems than in combined systems. Wastewater quality data show seasonal, daily, and hourly variations. Concentrations are also different in wet and dry periods. For design, the actual composition of wastewater should always be measured.



A typical composition of municipal wastewater is presented in Table 3.1.

Table 3.1 Composition of municipal wastewater (data according to references)

Parameter	Unit		Municipal wastewater		Urban runoff
			1	2	
TDS	mg/l	g/cap/day	400-2500		
TSS	mg/l	g/cap/day	160-1350	70-100	3-11000
BOD	mg/l	g/cap/day	120-1000	60-80	10-250
COD	mg/l	g/cap/day	280-2500	110-160	
Kjeldahl-N	mg/l	g/cap/day	30-200	11-14	3-10
Total-P	mg/l	g/cap/day	4-50	2 - 4	0.2-1
Coliforms	nr/100ml		10 ⁴ -10 ⁶ (faecal)		10 ³ -10 ⁸ (total)
Q (quantity)		l/cap/day		150-250	

Source:

1. UNEP/GPA, Guidelines on municipal wastewater management, 2004
2. UNEP/MAP, Guidelines on sewage treatment and disposal for the Mediterranean Region, Technical Reports Series No. 152, 2004

3.1.2 Industrial wastes

In cases of industrial wastewater discharges into the communal sewer system or directly into the water bodies, the estimation of the related quantities and loads is essential for an efficient wastewater management: toxic substances (e.g. heavy metals) originating from various industrial activities can, besides the harmful effects on the marine environment, block the biological process of wastewater treatment plants and damage the sewer pipelines. In Appendix II an overview of the composition of some industrial effluents is given.

3.2 Non-point sources

3.2.1 Fertilizers, animal wastes

The pollution of water by nitrogen and phosphorous from **agricultural activities** is of particular concern for the following reasons:

- there is a rising trend in pollution generation in most countries in the past years due to the increasing use of fertilizers with no sign of leveling off
- ground waters are seriously affected by the infiltration of nitrogen and phosphorous into aquifers through the soil
- nitrates and phosphorous are transported to rivers by surface runoff and then into the sea causing algae bloom (eutrophication)
- the control of this pollution source is very difficult due to its diffused origin.

Animal production has become more intensive in terms of number of animals per hectare due to increasing specialization at farm and at regional level. Consequently, manure production has increased in recent years. The animal waste is used for land

fertilization to a certain extent but the increased quantities produced lead to over-fertilization and consequently to severe pollution problems of ground waters: besides the leachate of nutrients, oxygen depletion and the introduction of pathogens are possible other side effects.

3.2.2 Pesticides

The use of pesticides in agricultural activities can also harm the water quality by:

- direct contamination e.g. herbicide application, mosquito control, rinsing of equipment
- indirect contamination by runoff (pesticides in rainwater, absorbed in soil particles) and by spraying
- leaching into the ground after application and from waste disposal containing pesticide residues.

3.2.3 Urban runoff – rainfall

Although the pollutant characteristics of urban runoff may vary widely, it should be stated that:

- concentrations in suspended solids exceed the levels found in municipal sewage
- bacterial concentrations may exceed those found in municipal sewage
- organic and inorganic pollutants from industrial and urban activities are often found in runoff

It is difficult to quantify the magnitude of pollutant discharge associated with urban runoff, since there are unstable factors affecting this loading such as density of urban and industrial development, type of sewer system serving the area (separate, combined), climatological conditions, etc. A typical composition in terms of municipal constituents is given in Table 3.1.

Runoff discharges increase peak flows in receiving waters and also considerably increase, in case of combined sewer collection systems, the peak wastewater quantities to be treated by treatment plants. They can also adversely influence, due to the contained pollutants, public health, stream eutrophication and aquatic life.

The preventive control measures of urban activities (i.e. use of better fuels, stack emission control, management of the use of chemicals), the management of the drainage system and of the end-of-pipe treatment facilities (i.e. screening for the removal of coarse particles) are recommended to reduce the adverse effects caused by runoff.

3.3 Impacts of municipal wastewater components

Effluent management requires wastewater treatment to a level, which will prevent further deterioration, secure protection and enhance the status of aquatic ecosystems, minimize risk of human disease and protect environmental uses/values of the waters. Inappropriate treatment of wastewater can cause significant and irreparable damage to receiving waters and land environment. Major threats to the environment are contaminants such as: for inland waters primarily phosphorus and nitrogen, for the sea

waters nitrogen and phosphorus, BOD/COD, suspended solids, heavy metals and toxic substances, pathogens. They can cause environmental damage and threat to human health, directly or indirectly, by food chain processes.

3.3.1 Aesthetics

Protection of aesthetic environmental values is necessary to avoid unacceptable odor problems, as well as other visual evidence of wastewater solids being discharged: color, floating materials, grease and oils. Generally, there should be no surface slick visible and no floatable wastewater solids, especially in the bathing areas.

3.3.2 Pathogens

Faecal waste from humans and animals contains pathogenic microorganisms (viruses, bacteria, fungi, and protozoan), which are directly harmful to human health. Water-related diseases, such as gastro-intestinal diseases, remain among the main health concerns. Raw wastewater contains many species of microorganisms which determine the potential health risk associated with recreational uses of receiving waters or consumption of seafood. Discharged by effluent, pathogens end up in the waters. The pathogens die off slowly in rivers, lakes and sea, and taint fish and shellfish. Rate of die off is significantly higher in sea than fresh waters. The level to which pathogens have to be reduced to ensure appropriate environmental values/uses is prescribed in appropriate standards.

Faecal coliforms are the most widely used indicators for likely presence of pathogens, selected because of their ability to indicate the presence of fresh faecal material and thus the possible source of pathogens.

3.3.3 Nutrients

Increased concentration of nutrients (phosphorus and nitrogen) in receiving waters usually leads to over-fertilization and blooms of algae or eutrophication, which alters the natural ecosystems. This can also in some cases cause development of undesirable species (e.g. cyanobacteria), which produce biotoxins that cause skin rashes on bathers. Once water organisms die off, they start rotting and deplete oxygen, which in turn affects all higher life forms in waters.

Waters are usually characterized as **sensitive** and **less sensitive**. A water body is considered as sensitive if:

- natural freshwater lakes, other bodies, estuaries and coastal waters are found to be eutrophic or to become eutrophic if protective action is not taken or have poor water exchange
- surface waters intended for the abstraction of drinking water contain more than the concentration of nitrate laid down under drinking water standard.

Less sensitive areas are marine water bodies or fresh-water areas in which wastewater does not affect adversely the environment as a result of morphology, hydrology or specific hydraulic conditions which exist in that area. Generally, these areas have high rate of water exchange/circulation and are not subject of eutrophication or oxygen depletion.

3.3.4 Toxicants

Toxicants in effluents, such as heavy metals (mercury, cadmium, etc.), and persistent organic substances, such as PCBs, can influence health, either as acute or chronic effects. Toxicants are a chronic risk to human health when they are:

- persistent in the aquatic environment
- bioconcentrated
- exerting a toxic effect after prolonged exposure to low concentrations of the toxic constituent.

The most common toxicants are heavy metals and chlorinated organics. PCBs and other persistent organics can be transferred through marine food chain.

The appropriate approach is to control toxicants at the source. The aim is to eliminate or to reduce pollution of water by certain dangerous substances to be found in industrial effluents discharged in municipal sewers.. To do so, it is necessary to set emission standards for sewers and waters, establish system of prior authorization, and implement programs to prevent or reduce pollution: generally industrial effluents connected with municipal sewers should have been pre-treated up to the level of raw municipal wastewaters. Toxicants can be partly removed from wastewater through biodegradation, or are retained in the sludge. The substances should not be allowed to contaminate wastewater sludge to such extent that the reuse of sludge can be prohibited.

The use of chlorine for disinfection is of special concern if the discharge is to water, as the concentration present can be harmful to aquatic life. Where chlorine use is the only practical disinfection option, the need for dechlorination of the effluent should be considered where there is not sufficient dilution through dispersion to ensure that chlorine concentrations are below toxic levels.

Toxic inorganic chemicals, like metals, in higher concentrations may cause synergistic or antagonistic effects in terms of toxicity in biological wastewater treatment plants.

3.3.5 Dissolved solids

Dissolved solids are portions of organic and inorganic solids that are not filterable. The impact of concentration and nature of soluble salts in treated effluent on land and fresh waters has to be considered very carefully. Salt discharged with effluent may alter salinity of fresh water, which may affect ecosystems, depending on the level of stress and ecosystem characteristics. It can also affect possible uses of fresh waters.

Dissolved solids in land application must be also very carefully considered. They may create serious environmental problems, particularly in association with higher water tables. This is especially a problem in the case when effluent or water is used for irrigation. Even if the concentration of dissolved salts is low it can result in a high concentration of salt in soil and reduction in crop production.

3.3.6 Suspended solids

Suspended solids originate from households and industrial wastes but also from urban runoff. The suspended solids render river and lake waters turbid, which in turn affects the biological productivity in water. Much of suspended solids are organic. When it settles out in lakes, rivers and estuaries it will start rotting creating a local oxygen-poor environment with same effects as BOD. Also, disposal of wastewater in shallow and closed seas may lead to this condition. It is the logical first step to build primary treatment to remove suspended solids prior to biological treatment.

3.3.7 Organic matter (BOD)

Organic matter causes depletion of oxygen in the surface water thus generating anaerobic conditions, which can lead to fish kills and bad smells.

The major impacts of municipal wastewater contaminants on the environment are summarized in Table 3.2.

Table 3.2 Major contaminants, relevant parameters to quantify the degree of contamination and their impacts on the environment

Contaminant	Impact on environment	Parameter
Suspended solids	Increase the water turbidity reducing the available light for organisms like sea grasses, corals. On sedimentation, benthic organisms are covered	TSS
Biodegradable organics	Anaerobic conditions leading to fish kills and bad smell (H ₂ S, NH ₃)	BOD
Nutrients	Excess may lead to eutrophication. Eutrophication stimulates algal growth. Degradation of dead algae will lead to anaerobic conditions (fish kills). It also stimulates the growth of toxic algae	Kjeldahl N, total P
Toxic compounds	Concentrate in shellfish and fish tissues (e.g. Hg pollution). Can interfere with microbial processes in biological treatment plants	Concentrations of compounds (e.g. heavy metals) in indicator organisms
Pathogens	Water-related diseases (e.g. gastro-intestinal, typhoid)	Bacteria (faecal coliforms), viruses, worm eggs

Source: UNEP/GPA, Improving municipal wastewater management in coastal cities, Training Manual, 2004

3.4 Effluent standards

3.4.1 Introduction

A quantitative approach of effluent characteristics of municipal sewage is here described, which can be used as a first guidance for establishing appropriate effluent standards by the relevant authorities. The definition and estimation of the parameters is based on international experience and has taken into consideration the existing knowledge of treatment achievements and their practical application, so that the adoption of these standards is technically feasible. However, the unconditioned acceptance of effluent standards being in use in other countries is unfavorable if the local conditions are ignored. As a matter of fact, the technical and financial capabilities for the achievement and control of desired effluent quality, the assimilative capacity of the receiving waters, the sea movements, etc. are some of the factors to be considered for reasonable and acceptable standards in each respective country. These factors have to be carefully analyzed under the existing local circumstances, in order to avoid the adoption of **too sophisticated treatment methods** and the related **excessive financial costs**.

3.4.2 Setting of effluent standards

Setting of effluent standards has to take into consideration, as said before, those factors, which determine the receiving seawater quality. As a general rule, the combined load of discharged effluents should never exceed the **self-purification capacity** of the receiving water body. For this purpose, several physical, chemical, biological and microbiological studies have to be elaborated to assess this capacity and to determine the maximum allowable inputs that will ensure that the desired levels of environmental quality are met. These technical assessments consider the fate and effects of various contaminants, amounts of input, and the existing natural characteristics of the relevant marine ecosystem (Chapter 2). Additionally, the preservation of the water quality needed for the related **water uses** is another dominant factor for the prescription of effluent standards, since the quality differences for each water use allow some deviations from the strictest limitations.

Pollution control strategies based on effluent standards apply a general principle to pollution control, taking into consideration the existing treatment technologies and the enforceability. This is particularly the case for municipal wastewaters where there are no significant differences in the wastewater composition and the existing technologies can achieve the best possible pollution load reduction. Generally the internationally adopted effluent standards can be achieved by applying **secondary (biological) treatment**. In § 4.4.6.2. various treatment processes and the relevant achievable final effluent concentrations are shown.

The member States of the European Union (EU) have adopted effluent standards for treated municipal wastewaters, which are presented in Table 3.3. These standards are achievable by applying secondary (biological) treatment, however the removal of nitrogen and phosphorous, strongly recommended in cases of effluent discharges into sensitive areas, needs the application of tertiary (advanced) treatment.

Table 3.3 EU effluent standards

Parameter	Concentration	Minimum percentage of reduction
BOD₅	25 mg/l O ₂	70 – 90 %
COD	125 mg/l O ₂	75 %
TSS	35 mg/l	90 %
Total N	15 mg/l *	70 – 80 %
Total P	2 mg/l *	80 %

* for communities between 10,000 and 100,000 population equivalents

Source: EU Commission, Guide: Extensive wastewater treatment processes adapted to small and medium sized communities, 2002

A general framework issued by the World Bank prescribes that domestic sewage, contaminated storm water and runoff must meet the maximum limits shown in Table 3.4 before being discharged into surface waters. This quantitative basis can be followed for issuing effluent standards, however, local conditions (i.e. sensitivity of receiving waters) should always be assessed and taken into consideration, in order to eventually apply more strict limit values for a more effective protection of the marine environment concerned.

Table 3.4 Limit values for effluent discharge into surface waters

Parameter	Unit	Limit values
pH		6 – 9
BOD	mg/l	50
COD	mg/l	250
Oil and grease	mg/l	10
TSS	mg/l	50
Heavy metals (total)	mg/l	10
Arsenic	mg/l	0.1
Cadmium	mg/l	0.1
Chromium (total)	mg/l	0.5
Chromium (6⁺)	mg/l	0.1
Copper	mg/l	0.5
Iron	mg/l	3.5
Lead	mg/l	0.1
Mercury	mg/l	0.01
Nickel	mg/l	0.5
Selenium	mg/l	0.1
Silver	mg/l	0.5
Zinc	mg/l	2
Cyanide (total)	mg/l	1
Cyanide (free)	mg/l	0.1
Ammonia	mg/l	10

Parameter	Unit	Limit values
Fluoride	mg/l	20
Chlorine (total residual)	mg/l	0.2
Phenols	mg/l	0.5
Phosphorous	mg/l	2
Sulfide	mg/l	1
Coliform bacteria	MPN/100 ml *	< 400
Temperature Increase	°C	< 3 **

* MPN = most probable number

** The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, 100 meters from the point of discharge should be used.

Source: World Bank Group, Pollution Prevention and Abatement Handbook – Environmental Guidelines, 1998

4 SELECTION AND DESIGN OF MUNICIPAL WASTEWATER COLLECTION, TREATMENT AND DISPOSAL SYSTEMS

4.1 Introduction

This chapter is the “core” of these guidelines, since the most important issues related to the selection of the appropriate wastewater collection, treatment and disposal systems are presented herein. For the selection of the appropriate municipal wastewater systems, the general framework, the aims and objectives to be met should be defined in such a way that the best possible technical solution will be selected. The term “best” is defined as the most technologically, environmentally and economically feasible collection, treatment and disposal system. In doing so, some principles and criteria should be considered in order to avoid wasting of resources and to achieve the appropriate level of protection of the marine environment.

This overall framework will allow the target groups of this document (decision makers/planners, regional/local authorities, inspectors) to understand the rather complex interrelations between the various options to be selected and the factors to be considered in choosing the most appropriate technologies. Therefore, the whole focus of the chapter is to point out those elements needed for the best possible selection of technological options without going into too many technological details. In this context it must be said that, although this is a rather “technical” chapter containing some technical issues of wastewater management technologies, by no means it is a “handbook” for the technical design of these systems. The necessary technical information can be found in many engineering textbooks and obviously it is beyond the overall scope of this document, which aims, as said before, to assist decision makers at central and regional level to take the relevant political/technical decisions for wastewater management. Therefore, the information contained attempts to show the main features related to the final selection of systems and especially the advantages/disadvantages of each option.

The chapter is structured in 2 parts: firstly, a **logical framework** to be followed for the successful execution of wastewater management schemes is shortly described. Then, the various general principles (**aims/objectives, selection criteria, pollution prevention**, etc.) and the appropriate selection criteria governing a successful wastewater management are described, giving an insight into the policy framework to be considered before moving to detailed selection of options. In the second part, various options for **collection, treatment** and **disposal** systems will be described focusing on main technical features needed to understand their functions. Special attention will be given to **submarine outfalls** for wastewater disposal.

4.2 Policy framework

Each wastewater management situation asks for a flexible, tailor-made set-up, in which necessary steps can be taken at different phases of the decision making process depending on available resources and capabilities. To do so, it is advisable to apply a

logical framework that incorporates a comprehensive set of carefully prescribed, logically related tasks. This framework should follow a dynamic and cyclic process, applicable also in situations where a wastewater management system is already in place. In principle each cycle consists of four major phases: problem identification, planning, implementation, enforcement and evaluation.

4.2.1 Assessment of existing situation

To design the best possible solution for wastewater management one needs to be familiar with the current situation but also with the historical development in the area concerned, which has led to today's problems. Monitoring (both performance of the system and environmental monitoring) of the existing situation should be based on:

- areas where impacts can be expected
- quantity and quality of wastewater from industries and small enterprises that is mixed with domestic wastewater and on the identification of the types of contaminants that cause serious harm to human health and the environment
- quantity and quality of urban runoff and the frequency with which it drains into the wastewater collection system
- assessment of geo-morphological, physical and environmental characteristics prevailing in the area where the wastewater management systems will be installed.

Furthermore, a careful estimation of the available resources required for the execution of each one of the solutions to be proposed, should be addressed, so that the relevant systems can be smoothly implemented in due time. Additionally, the needs and the overall response of key stakeholders (e.g. local communities, associations, etc.) towards the prospects of changing the existing situation by installing wastewater management facilities should be carefully evaluated, in order to avoid unnecessary reactions at a later stage, if they are not involved in the overall decision making process.

4.2.2 Planning

Since wastewater management systems should always be designed to serve not only existing but also future requirements, some important elements should be taken into consideration when decisions are taken such as:

- demographic and socio-economic projections, i.e. the rate of urbanization and the status of income (per capita and distribution), water supply and water demand
- the existing legal framework including standards and regulations
- the current institutional and the financial framework
- related sector policies, i.e. for water supply, solid waste management, land use planning and zoning, urban development
- national economic and development planning.

When designing a new system, obstacles can be identified while assessing the current situation or comparable situations elsewhere. In existing systems obstacles are at best recognized during an evaluation phase at a later stage. It is important to identify potential obstacles early in the process, so that solutions can be sought up front and incorporated in the new plan. For example, it may turn out that insufficient

institutional capacity exists, an obstacle that can be tackled by planning capacity building activities in the implementation phase, or when funding problems are recognized at an early stage, investment partners can be selected and involved from the beginning.

Planning and investments for wastewater management should be linked with planned socio-economic development and with overall river basins or coastal zone management. National economic and sector plans will provide relevant information on how and where to link plans and investments to wastewater management.

Once an analysis has been made of the current situation with its constraints and opportunities, an overall wastewater management plan can be formulated. Important strategic components to be considered in such a plan are:

- comply with existing environmental quality objectives and set effluent standards
- strive for prevention of pollution at source (prevention of release of toxic substances and minimization of wastewater) by applying best available techniques (BAT)
- consider re-use of municipal wastewater or sludge (in agriculture, horticulture, aquaculture, or for industrial cooling and processing)
- apply low-cost on-site sanitation wherever possible
- take impacts on the environment into account making use of the purification capacity of natural systems
- prioritize constituents and selection of cost-effective mitigation approaches, considering alternative technologies
- integrate policy with other sectors (water supply, land use planning)
- apply zoning of activities, e.g. like those of industrial development, tourism, etc.
- strive for an integrated approach to river basin management
- establish criteria to prioritize services to communities based on the level of health risks or state of living conditions and budgetary limits
- stepwise investment approach allowing eventual extension of facilities due to forthcoming demographic and/or socio-economic development (i.e. new economic activities)

Spatial differentiation in neighborhoods or suburbs should be allowed for, considering specific physical characteristics (slope, soil type, ground water level, existing infrastructure for water supply and sewerage) and the socio-economic situation (population density, local income, willingness and ability to pay and participate, land prices, energy costs).

Within the overall planning context, the conduction of **environmental impact assessment studies (EIA)** is a very important tool to be applied, which will define the environmental conditions to be respected, when a new wastewater management system has to be installed. The elements of these EIA studies are analyzed in Chapter 5.

4.2.3 Implementation

When all this planning exercise has been finalized, the various options for wastewater management have to be addressed and the final selection of the optimum combination

of collection, treatment and disposal systems should be made, taking into consideration all the mentioned elements (§ 4.3.3. and 4.4.). The implementing agencies need to be provided with management tools in the form of regulatory (standards, permits, fines, etc) and economic instruments (subsidies, taxes, covenants, etc). Such instruments should be supported by legislation and other types of authorization in order to:

- create measures to prevent pollution at the source
- enable use of economic instruments to promote waste minimization, pollution prevention and recycling
- ensure infrastructure is built applying adopted quality standards
- ensure sludge is handled following adopted quality standards
- enhance the capacity of authorities to enforce the instruments.

Institutional arrangements provide a framework for the various management tasks and tools, as well as for capacity building, raising awareness, and public participation.

4.2.4 Enforcement and evaluation

When constructed, installed and operated, the performance of the wastewater management facilities has to be monitored and evaluated, in order to detect any deficiencies and needs for improvement. Thus, it is important that goals and objectives are unambiguously formulated and quantifiable, so that they can be verified. Any discrepancies between actual and required performance must be communicated to the appropriate authorities, to initiate a new round of policy setting (policy adjustment).

Enforcing wastewater policy also entails:

- monitoring water quality, comparing actual values with agreed effluent and receiving water quality standards
- issuing discharge licenses
- collecting discharge fees or penalties.

4.3 Selection of wastewater management systems

4.3.1 Aims and objectives

The objective of wastewater management is to avoid long-term deterioration of fresh and seawater quality by appropriate treatment of wastewater and disposal of effluent aiming at sustainable protection and uses of fresh and seawater resources. The framework of objectives to be met is:

- avoiding health risks
 - preventing the degradation of the aquatic environment
 - promoting sustainable water uses
 - minimizing both adverse impacts to land and contamination of surface and ground waters when used in land applications
 - maintaining the agreed water quality objectives for receiving waters
 - maximizing the reuse of treated wastewaters.
-

These objectives have to be finally materialized into water quality objectives and effluent standards to be met, which consequently define the level of wastewater treatment before discharging effluents into the sea and the selection of the most suitable technology. However this above mentioned framework cannot be limited to the simple definition of the objectives of environmental protection but it also has to consider the existing social, cultural and economic environment in the region where the technological solutions will be applied. Even the best combination of systems and the highest expectations of environmental protection can lead to failures if the local society and the stakeholders involved are opposing the proposed solutions. This eventual reluctance can be based on lack of knowledge about the features of the proposed systems but also on more “down-to-earth” reasons such as economical considerations (“who will pay”), local society’s pre-occupations against “sophisticated” technical installations, inadequate monitoring capacities, etc. Therefore a **strategy** has to be formulated, in order to convince those stakeholders, who will play a key role in the policy-making and planning/implementation process, about the necessity and feasibility of the proposed solutions. This strategy should be based on:

- precautionary principle
- preventive actions
- polluter pays principle
- user pays principle
- waste hierarchy approach (prevention, minimization, treatment/disposal)
- participatory approach

When this strategy is successfully applied, the acceptance of the proposed solutions is feasible, particularly when the main stakeholders participate in the formulation and implementation of the strategy.

4.3.2 Stakeholders and strategy application

There are some stakeholders, who should be significantly involved in all phases of wastewater management at central and regional level. An indicative list is given below:

- **Government:**

Implementation and maintenance of compliance with policies and legislation in the field, provide environmental/wastewater agencies with authority, reporting and response to the community

- **State environmental agencies:**

Planning, setting standards and regulations, application of standards and regulations, monitoring and compliance assessment, technical assessment

- **Regional and local governments/municipalities:**

May be affected by the decisions of agencies/central government and of the wastewater authorities, construction/monitoring of public owned wastewater collection, treatment and disposal facilities, feedback to the planning process through the reporting mechanisms (i.e. systems’ failures, proposals for modifications/amendments

- **Wastewater companies/authorities (public and/or private):**
Managers of wastewater systems, constructors and operators of public/private wastewater treatment plants
- **Industrial companies:**
Compliance with permits for effluents discharged into the municipal sewage collection system
- **Public:**
Involvement in consultation processes for the planning. Reporting pollution incidents
- **Environmental and consumer non-governmental organizations (NGOs):**
Lobbying on behalf of the public with respect to water quality objectives, planning/ construction of treatment plants, pollution problems
- **Research institutions and universities:**
Research on environmental quality standards, toxicity assessment, water analysis, treatment technology development.

The harmonization of the many different objectives, which inevitably exist between all these stakeholders, is a major prerequisite for the final success in the whole planning and implementation phase: the acceptance of the proposed solutions, which necessarily evolves from a long lasting consultation process ensures the smooth operation of the facilities and avoids protests from those, who eventually feel that decisions were taken without their agreement. In order to come to this desirable result, the above-mentioned strategy has to be convincingly presented by those, who have the responsibility for the final decisions. Concerning wastewater management systems, this strategy should be explained in its aspects as follows:

Strategy elements	Explanation
precautionary principle	Actions (i.e. construction of facilities) to be taken before existing pollution problems become irreversible
preventive actions	Measures to reduce water consumption/ uptake and therefore to produce the least possible wastewater quantities
polluter pays principle	Any industries to be connected with the municipal sewer system have to construct and operate their own pre-treatment facilities
user pays principle	The investment and operational costs of the facilities have to be covered by the municipalities to be served
waste hierarchy approach	End-of-pipe systems (i.e. treatment/ disposal facilities) will be constructed after all preventive actions, wastewater minimization/recycling techniques will have been applied
participatory approach	Initial decisions taken by governmental/ central authorities have to be discussed and agreed upon with the local society: regional authorities, NGOs, public

To ensure sustainability in wastewater management the responsibility for services should be delegated to the local level, while central authorities remain responsible for strategic planning, policy and regulatory aspects. Essential ingredients of such an enabling environment include:

- clearly defined and consistent responsibilities
- a legal structure reflecting these responsibilities
- an effective regulatory body
- appropriate regulations, codes, and standards
- reliable and updated information.

Public and private institutions that will be responsible for the actual provision of services should have a certain degree of autonomy. They should:

- participate in overall development planning
- have management and operational autonomy on local level
- be permitted to raise funds from sources most suitable to their needs
- develop their own cost-recovery policies and procedures
- have autonomy in human resource development matters.

The application of this step-by-step approach and the decentralization of decisions and activities will ensure the widest possible agreement of all stakeholders on the decisions taken, so that their implementation at a later stage will not face major problems.

4.3.3 Options for wastewater management

Wastewater management options should address the management of the wastewater sanitation system as a whole (users/wastewater, collecting system, treatment and disposal) and each of the aspects individually.

The general aspects are:

- application of waste minimization schemes
- management of collection and treatment system (wastewater and sludge)
- effluent reuse
- effluent discharge to:
 - land
 - coastal waters (marine disposal system)
 - inland waters

Choice of preferred options is made after considering the aims/objectives and the strategy mentioned above (§ 4.2.1. and 4.2.2.):

- public health and environmental impacts
- social needs and community expectations
- regional and state ecologically sustainable development policy

- associated river basin/catchment management policy and plans
- national, international and regional obligations
- feasibility- technical, operational, financial, social and environmental criteria, options and alternatives
- cost of the scheme and relevant social impacts
- availability and feasibility of technology.

For any pollution control initiative an analysis of cost-effectiveness needs to be made and compared with all conceivable alternatives. From a planning perspective, some important questions need to be addressed before any choice is made:

- Can pollution be minimized by recovery technologies or public awareness?

Water savings made by households can really downscale the final wastewater management facilities to a considerable extent causing reduction of investment and operational costs

- Is treatment most feasible at centralized or decentralized facilities?

Centralized treatment is often devoted to the removal of common pollutants only and does not aim to remove specific individual waste components. However, economies of scale render centralized treatment cheap whereas decentralized treatment of separate waste streams can be more specialized but economies of scale are lost. By enforcing land-use options or by separating or pre-treating industrial discharges before they enter the municipal sewer, the overall treatment becomes substantially more effective.

- Can the value of resources in domestic sewage be recovered by reuse?

Wastewater is a poorly valued resource. In many arid regions of the world, domestic and industrial sewage only has to be "conditioned" and then it can be used in irrigation or in industries as cooling and process water. Treatment costs are considerably reduced and pollution is minimized. Unfortunately, many of these potential alternatives are still poorly researched and insufficiently demonstrated as the most feasible.

In the selection of the options it is necessary to apply a hierarchical approach for waste management by encouraging wastewater producer, services providers and authorities to choose waste management options towards the top of the hierarchy, as follows:

- no use or production of unwanted substances
 - waste minimization or reduction of waste production quantities
 - re-use/decrease of the amount of waste to be finally treated and discharged into the environment
 - recovery and convert
 - treatment
 - dispose and disperse.
-

4.3.4 Choosing a sanitation technology

Having in mind all aspects described above, the various options for selecting the appropriate sanitation technology (collection, treatment, disposal) are to be carefully evaluated. While selecting a sanitation technology one needs to consider pollution prevention at the source, on-site treatment, off-site transportation coupled with natural treatment and/or re-use and, if all former options are exhausted, conventional treatment. Four different technology options can be distinguished ranging from prevention up-front and simple low-input systems to sophisticated high-input systems:

1. start with pollution prevention and wastewater reduction at the source
2. apply on-site treatment
3. apply simple off-site treatment such as natural treatment of collected wastewater using the natural self-purification capacity of receiving soil or water bodies and re-use and valorization using simple technology and ecological engineering so converting wastewater into a valuable resource
4. install conventional off-site wastewater collection and centralized, high technology, end-of-pipe treatment.

The technology should be environmentally sound, appropriate to local conditions, applicable and efficient in the context of the entire river basin, and affordable to those who must pay for the services. Other aspects to consider during the technology selection process are:

- awareness and the need for changes in behavior in the local society
- workable policies and regulations
- possibilities for enforcement
- technical performance and reliability (under variable wastewater flows, compositions and operational problems)
- institutional manageability (planning, design, construction, operation and maintenance capacity, including local availability of skilled human resources)
- investment, operation, and maintenance costs.

Table 4.1 gives an overview of main characteristics of wastewater management technologies.

**Table 4.1 Technologies for wastewater management
(with relative costs, environmental impact and maintenance requirement)**

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

Source: UNEP, “Guidance on municipal wastewater”(in collaboration with Murdoch University Environmental Technology Center), November 2000

4.4 Wastewater management systems

4.4.1 Waste minimization

Waste minimization is a major priority of any sustainable wastewater management strategy and should be appropriately addressed as the first step. The application of waste minimization practices will push the volume of wastewater and quantity of potential pollutants to a minimum and consequently the risk to the human health and the environment.

The most important elements to be considered are:

- reduction of contaminants in industrial wastes discharged to the collection system
- minimization of wastewater flows by applying water conservation and demand management principles to industrial, commercial and domestic customers
- management of domestic products that may add contaminants to the wastewater flow
- management of collection systems to exclude infiltration and storm water
- control of product constituents (organic matter, metals) and especially home and industrial dumping of chemical substances.

Reduction of the quantity of the pollutants being discharged to the wastewater system also has a positive impact on the entire system, such as: savings in treatment plant operation cost and resources used, reduction in sludge production and costs of sludge treatment and disposal, maintenance cost of collection system and treatment plant, etc.

Reduction has a direct impact on the capacity of the system as a whole, which can be appropriately smaller, as well as the relevant investment and operational costs. However, the most positive aspect of the reduction is minimization of the negative impact to the environment.

A range of actions in different areas can be applied for waste minimization and at different management levels. Usually, actions in the areas are:

- reduction of inappropriate use of potable water: water saving rules, such as requiring the use of water saving devices (showers, toilets), pressure reduction, etc.
- incentives, such as quantity and quality based charges for major industrial and commercial discharges and user-pays for domestic wastewater
- education/training on the use of water-efficient appliances, on-site recycling of materials and environmental friendly products and practices
- regulation, control or ban of use/import/production of certain type of products, devices and appliances

4.4.2 On-site treatment

After pollution is prevented to the largest possible extent, on-site treatment should be considered as the second step. On-site sanitation systems for wastewater collection and treatment are effective when little or no piped water is available. Such on-site

systems are applicable at the level of a household, a community, or an apartment block. Package plants are used mostly for resorts, hotels, and other public buildings.

On-site systems use either a septic tank or a pit for collection. A septic tank is a watertight tank that collects wastewater from toilets, showers, sinks and other household utilities via a pipe. The wastewater will flow through the tank, and the solids will settle to the bottom of the tank. The clarified tank effluent flows out of the tank into a drainage field or overflows into a drainage system. The area needed for effluent disposal depends on the flow rate and local soil infiltration rate. The solids (septage) that accumulate in the pit or tank (some 40 liters per person per year) have to be removed periodically. The septage is usually discharged into nearby sewage treatment plants or in a separate waste stabilization lagoon. A septic tank will remove 30 to 50% of BOD and 40 to 60% of suspended solids. In properly designed septic tanks with soil absorption, the soil will remove the remaining BOD, suspended solids, bacteria and viruses from the effluent.

4.4.3 On-site vs. off-site treatment

In densely populated areas, the volume of generated wastewater may exceed the capacity for ground infiltration. The additional risks of groundwater pollution and soil destabilization (affected by factors such as ground porosity, slope, and high water tables) often limit the possibility of on-site treatment, so that some form of more expensive wastewater collection and centralized treatment is needed. The unit cost for off-site sanitation decreases significantly with increasing population density, but constructing a sewage collection system for an entire city often proves to be very expensive. In cities where urban planning is uncoordinated, implementation of a balanced mix of on-site and off-site sanitation is most cost-effective. The deciding factor in these cost calculations is the cost of the collection and conveyance system whereas additional limiting factors for on-site treatment are whether shallow wells used for water supplies need to be protected, the population density, the soil permeability and the unit cost. To minimize groundwater contamination, a typical surface loading rate of $10 \text{ m}^3 \text{ ha}^{-1} \text{ d}^{-1}$ is recommended provided that prevailing groundwater tables ensure at least 2 m unsaturated flow in a vertical direction.

In addition to technical, logistic and financial criteria, reliable management by a local authority is essential for sustainable functioning of the system. Most off-site treatment technologies benefit from economies of scale.

4.4.4 Natural treatment systems

Natural wastewater treatment systems are simple methods, which, mostly without mechanical aeration, use natural aeration (ponds, lagoons) or soil bacteria (land application) to reduce the organic content of wastewater. They can be applied where adequate land area is available and sophisticated systems (i.e. activated sludge) can be avoided. Anaerobic ponds, on the contrary, use anaerobic microbiological processes to remove organic load without the need for energy input.

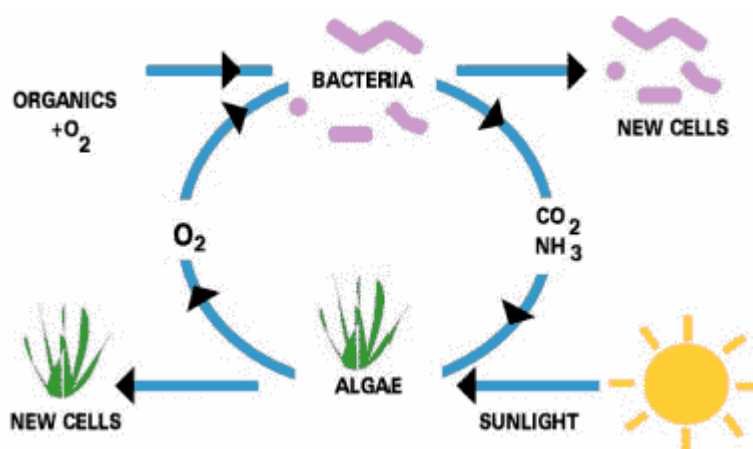
4.4.4.1 Ponds – lagoons

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 (days), removal of pathogenic bacteria and viruses by natural die-off is greater than in an activated sludge treatment plant (residence time usually several 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 percolation of wastewater into the soil and groundwater that 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 stabilization 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.

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 carbon dioxide, while algae take up carbon dioxide released by the bacteria and produce oxygen that is used by the bacteria.



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. 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, the middle ones facultative and the last few aerobic. 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 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.

4.4.4.2 Land based treatment

Land applications have been used to return the discharged water to the water cycle. It includes systems such as evaporation ponds, soakage systems and irrigation by which water returns to the water cycle by evaporation and evapotranspiration or infiltration. In this case irrigation has a goal to maximize the discharge of water and its return to the water cycle.

This type of discharge of effluent has been traditionally used as an on-site solution for individual houses where wastewaters, after local on-site treatment, have been discharged on land by some type of drainage system. Land application for bigger systems is rare but if it is used, then, in most instances, involves the irrigation of land owned by the sewerage authorities. In this case the principles of effluent reuse have to be applied.

Land application aims to utilize the water and nutrient components in a suitable way with minimum impacts on:

- soil
- surface water
- groundwater
- ecosystem at or near the application site
- human activities near to site.

Solution/schema for land application depends strongly on the local situation and characteristics. The most important factors are climate, availability of land, topography, groundwater, soil properties, existing and planned land use.

The basic principles for land application are:

- secure long-term sustainable land use avoiding build up of any substances in the soil
- the effluent is not detrimental to the vegetation
- avoid any change of the soil structure
- any runoff to surface waters and/or percolation to groundwater should not affect the environmental values of the receiving waters
- no gaseous emissions to cause nuisance odor
- no aerosol formation to cause health and other problems in neighboring areas
- implement insect control measures to reduce mosquitoes nuisance

Land application is a feasible alternative for inland communities, especially smaller communities in arid and semiarid areas for total effluent disposal or surplus effluent disposal. This method is also feasible in areas where direct discharge to the surface and ground water is not permitted, such as water for drinking purposes or very sensitive waters. Application and loading rate have to be carefully planned, managed and monitored so that any discharge in groundwater and surface waters will comply with the required quality of receiving waters and environmental values/water uses. Infiltration from land application results in aquifer recharge. In any case, it is more suitable if effluent reaches water resources by infiltration than runoff, providing that infiltration will result in additional treatment of effluent. As a matter of fact, land application can be used as a method for artificial recharge of aquifer using appropriate levels of treatment.

4.4.5 Wastewater reuse systems

4.4.5.1 Introduction

Effluent reuse serves an important function in water resources management by providing a possibility to produce a quality source of water for irrigation, industrial, and urban water requirements in a region. With many countries facing severe water shortages, reuse of water for irrigation and industrial purposes is gaining ground. It also generates income and reduces costs.

Depending on the level of wastewater treatment, it can be re-used in a wide variety of ways, ranging from non potable uses like toilet flushing or industrial cooling water to re-uses with higher health related quality requirements such as composting to fertilize and improve soil structure, food crop irrigation, or recharge of potable groundwater aquifers.

Before a sound decision can be made on re-use of wastewater, a number of issues need to be considered and assessed. There are common planning aspects such as technological and economic feasibility, legal issues and other institutional arrangements. In a survey, issues like attitudes towards re-use, existing water rights and consequences of re-use, willingness and capability to pay, capacity to participate

in planning, implementation, management, quality and quantity requirements of treated re-useable products should be considered.

Perceptions of health risks in wastewater re-use vary considerably among different social, cultural and economic groups. This fact and the absence of comprehensive international guidelines has led countries to develop their own approaches for re-use of wastewater.

4.4.5.2 Wastewater reuse for agriculture

Treated wastewater from off-site treatment plants can be reused for irrigation of parks and gardens, agriculture, 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 e.g. during raining seasons. 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 is also an option that can be considered.

Land application for treatment of wastewater described in § 4.4.4.2. (Slow rate land application and grass filtration) when combined with growing of grasses for grazing by sheep or cattle can properly be considered as treatment and reuse of wastewater.

4.4.5.3 Wastewater reuse for aquaculture

In most aquaculture systems, wastewater is not reused directly in aquaculture and the nutrients contained in the wastewater are used as fertilizer to produce natural food such as plankton for fish. These 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.

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 are a number of constraints to wastewater-fed aquaculture and they need to be considered where the practice is considered to be an option. They include:

- lack of knowledge of aquaculture as a technical option in wastewater treatment and reuse
 - limited available sites in peri-urban areas where wastewater is available for reuse
-

- rapid urbanization in developing countries threatens the existing wastewater-fed systems
- rapid eutrophication from urbanization and industrialization
- rapid industrialization contaminates nutrient-rich domestic wastewater with industrial wastewater.
- social and cultural acceptance of wastewater-fed aquaculture products

A correctly managed system would limit public health risks and wastewater should never be reused without prior treatment if the produce (fish or aquatic vegetables) is intended for direct human consumption.

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, the Middle East and in Latin America.

4.4.5.4 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 fulfill the lower range of this requirement, e.g. water for cooling towers. Secondary treated wastewater after chlorination may be adequate for this purpose.

4.4.6 Conventional wastewater collection, treatment and disposal systems

Under the term "conventional" are classified all collection, treatment and disposal systems, which do not apply any of the abovementioned methods (natural systems, minimization methods, wastewater reuse) and mostly aim at serving larger communities. They are characterized by an extensive collection system, physical/physico-chemical and biological treatment systems and the final effluent disposal into the sea by submarine outfalls.

4.4.6.1 Collection systems

In planning a collection system, the following parameters should be carefully considered:

- design period
- wastewater characteristics
- separate or combined system

4.4.6.1.1 Design period

The following parameters should be considered:

- population and area served by the existing system
- expected population growth in the area concerned

- surrounding settlements to be also served by the planned system
- trends of industrialization in the area
- design capacity of the existing system and possible coverage of future trends

4.4.6.1.2 Wastewater characteristics

a) Quantity: Up to 80% of water supply may be expected to reach the sewer, therefore a quantity of 180 – 250 l/cap/day can be used for design purposes. As reference, the population at the end of the design period should be considered.

b) Quality: The typical composition (see Table 3.1.) should be expected not allowing substances, which eventually will affect the sewer's construction material (i.e. industrial wastes).

c) Design flow: The design flow is always higher than the average quantity predicted, in order to allow the system to handle hourly and seasonal variations as well as the unavoidable infiltration rates.

4.4.6.1.3 Separate – combined system

Combined sewerage systems carry sewerage and storm water in the same conduit. Separate systems transport storm water and sewage through separate storm water drains and sanitary sewers, respectively. This allows for more consistent treatment process performance. Combined sewerage is most appropriate for more industrialized regions with a phased urban development, with an even rainfall distribution over the year and with soil erosion control by road surface paving.

Combined sewerage is generally less suitable for developing countries, because both sewerage and treatment are expensive, especially in regions with high rain intensities during short periods of the year. It requires simultaneous investment for drainage, sewerage and treatment. Treatment plants connected to a combined sewer system have to be designed to accommodate two to five times the peak dry weather flow, which raises cost and adds to control complexity. Additionally, the water velocity in a combined sewer may be very low during dry periods, so that solids are deposited causing bad odors and corrosion of the pipe material. A further disadvantage of the combined sewer system is the fact that extreme peak flows cannot be handled and overflows containing wastewater are discharged to surface water.

Separate systems allow the sewer system and the treatment plant to be designed on the basis of smaller, more regular and more concentrated wastewater flows (“dry weather flow”) and thus investment costs can be considerably reduced.

4.4.6.2 Wastewater treatment systems

4.4.6.2.1 General description

Wastewater treatment involves various processes used individually or in series to obtain the required effluent quality. Standard and most important processes are:

A) Pre-treatment

Removal of gross solids, coarse suspended, floating matter, grease and oils by simple devices such as bars/screens. The main aim of this process is to protect outfall and prevent visual nuisance.

B) Primary treatment

Removal of settleable solids by a physical and/or chemical process involving settlement of suspended solids, in which the BOD₅ of the incoming wastewater is reduced by at least 20% before discharge and the total suspended solids (TSS) of the incoming wastewater by at least 50%. The main aim of this process is to protect secondary (biological) process and submarine outfall operation, provide minimal environmental protection around point of discharge and prevent visual and other nuisance.

C) Secondary treatment

Removal of most of the remaining contaminants, TSS, colloidal and dissolved organic matter. It means treatment of urban wastewater by processes generally involving biological treatment with a secondary settlement device or other processes, in which contaminants in incoming wastewater are reduced by at least:

- BOD₅ 70 - 90%
- COD 75 %
- TSS 70 - 90 %

The main aim of this process is environmental protection from oxygen depletion and prevention of visual and other nuisance.

D) Tertiary treatment

Removal of nitrogen (N) and phosphorus (P) following the secondary treatment. It means treatment of urban wastewater by processes, in which contaminants in incoming wastewater are reduced by at least:

- total P 80% and/or
- total N 70 - 80 %

The main aim of this process is environmental protection from eutrophication and prevention of visual and other nuisance.

E) Disinfection of effluents

Reduction of pathogens to levels acceptable for the reuse or discharge of treated wastewater in most cases into receiving waters. The main aim of this process is reduction of health risk.

F) Advanced wastewater treatment

Further improvement of the quality of effluent by processes such as granular media filtration, ion exchange, micro filtration and membrane technology. The main aim of this process is further improvement of effluent quality due to enhanced quality requirements (e.g. reuse).

The most common level usually includes pre-treatment, primary and secondary treatment in series or combined in varying configurations. Secondary treatment is normally a prerequisite of advanced treatment and disinfection. Tertiary as well as advanced wastewater treatment, is generally associated with protection of nutrient-sensitive areas, or specific uses of water bodies such as drinking purposes. Advanced treatment and disinfection are also associated with effluent reuse.

In Table 4.2 typical combinations of treatment processes are presented.

Table 4.2 Combinations of physico-chemical and biological treatment processes

Raw wastewater	Typical concentration (mg/l)	1st unit		2nd unit		3rd unit	
		Process	Typical out concentration	Process	Typical out concentration	Process	Typical out concentration
SS	200	Sedimentation	80-100	Act. sludge	10-30	Filt.	3-7
		Coagulation/sed.	10-30	Act. sludge	10-30	Filt.	3-7
		Coag./sed.	10-30	Filtration	3-7		
		Activated sludge	10-30	Filtration	3-7		
BOD ₅	200	Sed.	130-150	Act. sludge	10-30	Filt.	1-3
		Coag./sed.	80-100	Act. sludge	10-30	Filt.	1-3
		Coag./sed.	80-100	Filt.	80-90	Adsorption	5-15
		Act. Sludge	10-30	Filt.	1-3	Ads.	0-2
COD	400	Sed.	50-100	Act. sludge	50-100	Filt.	40-60
		Coag./sed.	50-100	Act. sludge	50-100	Filt.	40-60
		Coag./sed.	160-180	Filt.	100-160	Ads.	20-30
		Act. Sludge	50-100	Filt.	40-60	Ads.	5-10
P	10	Coag./sed.	2-5	Filtr.	0-1		0-2
		Coag./sed.	2-5	Act. sludge	1-5		0-2

Source: UNEP/MAP, Guidelines for authorizations for the discharge of liquid wastes into the Mediterranean Sea, 1996

4.4.6.2.2 Technical/economical features related to treatment methods

Primary or mechanical treatment involves the physical settlement of solids in sedimentation tanks. The treatment consists of screening and grit removal to eliminate sand, gravel and other coarse solids from the influent wastewater stream, followed by a gravity separation process to remove suspended solids.

Secondary biological treatment processes are based on the metabolic activity of aerobic microorganisms and the supply of air to reduce the organic material (expressed as BOD) contained in wastewater. By increasing the area of contact

between wastewater and the air, the opportunity for oxygen take-up from the air increases. The most common ways to achieve this are:

- produce activated sludge by using mechanical agitators such as a rotating biological contactor or by blowing air through wastewater, or
- create 'bacteria beds' or trickling filters, by allowing water to trickle through a bed of stones (or another suitable medium), so that it spreads as a fine film and is in contact with both air and the oxidizing organism.

The **activated sludge** system is a versatile system offering operational flexibility and high reliability. It allows integration of nutrient removal processes, such as nitrification, denitrification and biological phosphorous removal. Rotating biological contactors are frequently used for small wastewater flows, such as from hotels and small compounds.

Although **trickling filters** are more easily operated and consume less energy than activated sludge processes, they have a lower removal efficiency for solids and organic matter, they are more sensitive to low air temperatures and can become infested with flies and mosquitoes. They also do not have the capacity for nutrient removal.

Tertiary treatment is directed at the removal of nutrients (nitrogen and phosphorous). Phosphorous removal processes involve either the addition of chemicals to precipitate phosphorous or controlled biological reactions to grow bacteria with high phosphorous levels and settle them out. Nitrogen removal is based on biological reactions to convert ammonium and organic nitrogen into nitrate (nitrification) and then into gaseous nitrogen (denitrification).

Economies of scale can play an important role in designing conventional wastewater management and infrastructure. From a managerial and operational point of view, planning wastewater treatment based on administrative boundaries of small municipalities rarely makes sense. But the incentive to centralize the operation and capacity of treatment plants is balanced by the increasing cost of transporting wastewater over longer distances.

Large plants serving more than 300,000 people are able to invest in technologies that substantially lower operational costs for maintenance, energy, and sludge disposal: e.g. only large plants can invest in sludge digestion reactors with methane gas recovery and gas-powered generators. Enough electrical power can then be generated to supply all the power required by the plant, which is often the largest operational expenditure.

An overview of the most common units, which are applied in conventional municipal wastewater treatment and form an acceptable minimum system, is summarized below:

- *Pre-treatment:* Within a wastewater treatment plant, raw wastewater first enters a grit chamber. As the wastewater flows gently through the chamber, solids (such as sand, grit and gravel) settle to the bottom, and are removed by buckets, while large suspended matter is removed by screens. The wastewater is then pumped into a primary sedimentation tank.

- *Primary Sedimentation Tank:* As the wastewater flows slowly in a primary sedimentation tank for two to three hours, organic solids gradually settle to the bottom. This mass of solids is called raw sludge, and is sent to a sludge treatment facility for further treatment. To make the most of available land, double-decker sedimentation tanks are used at some wastewater treatment plants.
- *Aeration Tank:* The major role of the aeration tank is to remove the soluble organic material that escaped treatment in the primary sedimentation tank and to provide further removal of suspended solids. In order to ensure the sufficient and rapid decomposition of organic material, it is necessary to promote the growth of microorganisms capable of absorbing these soluble organic materials. In the activated sludge process, the aeration tank mixes and agitates wastewater and activated sludge. During the 6 to 8- hour aeration period, the microorganisms absorb the organic matter as nutrients, and they grow as a result. This decomposes the organic matter into inorganic substances such as water and carbonic acid gas. The microorganisms adhere to suspended solids and then form clots that can be easily removed as sediment.
- *Secondary Sedimentation Tank:* While the mixture from the aeration tank flows slowly in a secondary sedimentation tank, it is separated into solids (activated sludge) and an aqueous portion (or supernatant). Part of the activated sludge is returned to the aeration tank, and the rest is treated in a sludge treatment facility. The secondary effluent is usually discharged into the receiving environment after chlorination. Following advanced treatment, part of the sewage treatment plant effluent is often used for miscellaneous purposes in the plant and as water for toilets in buildings. In addition, it can be used to augment the flow of smaller streams. In some cities such as Tokyo, double-decker secondary sedimentation tanks are used to make more effective use of available land.
- *Sludge Treatment:* The raw sludge from the primary sedimentation tank and the excess sludge are pumped to thickening tanks. In the thickening tank, the volume of the sludge is reduced to about one-quarter of the volume of the raw sludge. The thickened sludge is then mechanically dehydrated. The sludge is sometimes sent to a digestion tank after being thickened. There are different types of sludge drying (or dehydrating) machines, including vacuum, centrifugal, filter press, and belt press. Dehydrated sludge is often burned and becomes ash. The ash generated by incinerating sludge is usually about 1% of the original sludge volume.

4.4.6.2.3 Sludge treatment 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 due to the removal of solids from wastewater. Additionally soluble organic substances are converted to bacterial cells, which have also to be removed.

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) and is potentially beneficial as fertilizers for plants. The organic carbon in the sludge, once stabilized, is also desirable as a soil conditioner, because it provides improved soil structure for plant roots.

Options for sludge treatment include:

- **stabilization:** removal of the contained high BOD by aerobic or anaerobic process
- **thickening:** removal of water by sedimentation
- **dewatering/drying:** further removal of water by filter presses, centrifuges or drying beds
- **reuse:** as soil conditioner in agriculture
- **disposal:** in landfills or in incineration plants

Table 4.3 gives an overview of the various treatment processes applied for sludge treatment and disposal.

Table 4.3 Sludge treatment and disposal processes

Process	Unit operations
THICKENING	<ol style="list-style-type: none"> 1. Gravity 2. Flotation 3. Centrifugation
STABILIZATION	<ol style="list-style-type: none"> 1. Chlorine oxidation 2. Lime stabilization 3. Heat treatment 4. Aerobic digestion 5. Anaerobic digestion
CONDITIONING	<ol style="list-style-type: none"> 1. Chemical 2. Elutriation 3. Heat treatment
DEWATERING	<ol style="list-style-type: none"> 1. Vacuum filtration 2. Filter press 3. Horizontal belt filter 4. Centrifugation 5. Drying beds
DISPOSAL/REUSE	<ol style="list-style-type: none"> 1. Land application <ul style="list-style-type: none"> - to croplands (reuse) - to marginal land for land reclamation - to forest land - to dedicated sites 2. Composting 3. Land filling 4. Incineration 5. Recalcination (a lime recovery process in which the calcium carbonate in sludge is converted to lime by heating at 980°C) 6. Lagoons

4.4.7 Alternative wastewater treatment systems

There are various wastewater treatment and disposal methods, which have become attractive especially in areas with appropriate soil conditions (e.g. in arid land areas) such as **underground storage of water** and **water injection into the ground** as well as the use of **membranes** for wastewater treatment.

Groundwater recharge with reclaimed municipal wastewater is an approach to water reuse, in order to:

- reduce, stop, or even reverse declines of groundwater levels
- protect underground freshwater in coastal aquifers against saltwater intrusion from the ocean
- store reclaimed municipal wastewater for future use

There are several advantages to storing water underground:

- the cost of artificial recharge may be less than the cost of equivalent surface water reservoirs
- the aquifer serves as an eventual distribution system in underground and may eliminate the need for transmission pipelines or canals for surface water
- water stored in surface reservoirs is subject to evaporation and to potential pollution problems
- suitable sites for surface water reservoirs may not be available or environmentally acceptable

The most common and widely accepted method for aquifer recharge is the use of **percolation basins** (large land requirements). Another method for groundwater recharge includes **direct injection** into the saturated zone (requires high technology pre-treatment). An emerging method for groundwater recharge is the use of **vadose zone injection wells** provides some of the advantages of both recharge basins and direct injection wells (Figure 4.2). The major characteristics of the three technologies are summarized in Table 4.4.

Figure 4.2 Methods for aquifer recharge

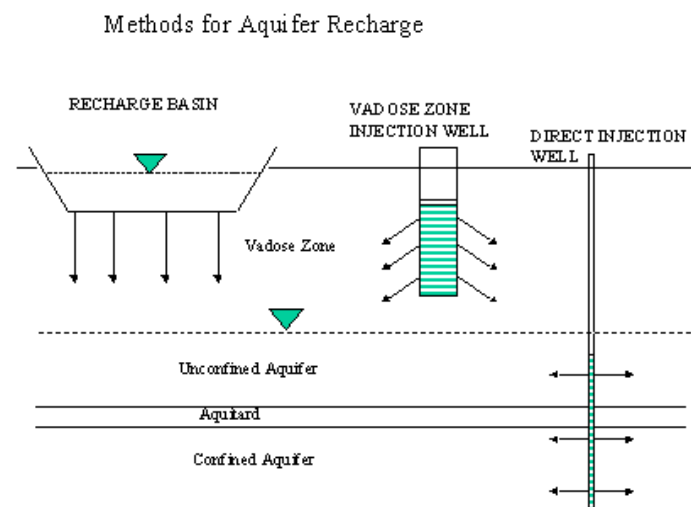


Table 4.4 Major characteristics of aquifer recharge methodologies

	Recharge Basins	Vadose Zone Injection Wells	Direct Injection Wells
Aquifer Type	unconfined	unconfined	unconfined or confined
Pre-Treatment Requirements	low technology	removal of solids	high technology
Estimated Major Capital Costs US\$	land and distribution system	\$25,000-75,000 per well	\$500,000-1,500,000 per well
Capacity	1000-20,000 m ³ /ha-d	1000-3000 m ³ /well-d	2000-6000 m ³ /well-d
Maintenance Requirements	drying and scraping	drying and disinfection	disinfection and flow reversal
Estimated Life Cycle	>100 Years	5-20 Years	25-50 Years
Soil Aquifer Treatment	Vadose zone and saturated zone	Vadose zone and saturated zone	saturated zone

Source: UNEP – IETC, International Symposium on “Efficient Water Use in Urban Areas - Innovative Ways of Finding Water for Cities”, 1999

The estimated costs associated with the use of recharge basins are highly variable since they depend on infiltration rates and land values. Infiltration rates are a function of the soil hydraulic conductivity and the development of mounding on the groundwater table. Average infiltration rates must consider the cyclic operation of the recharge basins that includes both wetting and drying periods. Average infiltration rates can vary from 8 to 150 cm/d depending on the soil type and development of clogging layers.

Four water quality factors are particularly significant in groundwater recharge with reclaimed wastewater:

- microbiological quality
- total dissolved solids
- heavy metals
- concentration of stable organic substances

Thus, groundwater recharge with reclaimed wastewater presents a wide spectrum of technical and health challenges that must be carefully evaluated.

Pretreatment requirements for groundwater recharge vary considerably depending on purpose of groundwater recharge, sources of reclaimed wastewater, recharge methods and location. Although the surface spreading method of groundwater recharge is in itself an effective form of wastewater treatment, a certain degree of pretreatment must be provided to untreated municipal wastewater before it can be used for groundwater recharge.

SUCCESS STORY 1

SULAIBIYA WASTEWATER TREATMENT AND RECLAMATION PLANT, KUWAIT

Scheduled for completion in December 2004, the Sulaibiya Wastewater Treatment and Reclamation Plant will be by far the largest facility of its kind in the world to use reverse osmosis (RO) and ultrafiltration (UF) membrane-based water purification.

The project is intended to treat wastewater to potable quality for non-potable uses in agriculture, industry and aquifer recharge. The plant has an initial daily capacity of up to 375,000m³ and is designed to be extendable to 600,000m³/d in the future.

At a total project cost of \$430 million this is the first transaction of its size to be funded solely by domestic banks.

PROJECT DESIGN

Two major problems led to the implementation of the Sulaibiya wastewater treatment and reclamation project. Firstly, the existing WWTP at Arddiya had reached capacity and, since there is no scope to extend it, the increasing volume of wastewater flow required the provision of alternative treatment facilities. Secondly, the country's brackish water resources are now no longer sufficient to meet the growing demand for non-potable use. The project has been designed as an integrated response to resolve both of these issues.

The Ardiya plant acts as a pre-treatment phase, receiving, screening and degreasing the wastewater inflow. A 25km-long main feeder pipeline conveys the pre-treated flow to the new Sulaibiya WWTP, where it is treated to potable water standards. The Sulaibiya plant itself comprises three elements - biological nutrient removal, RO / UF membranes and sludge treatment. A new 1km product water pipeline transports the finished effluent to the nearby brackish water gathering center prior to use, while the membrane system brine overflow is returned to the sea via another new 25km pipeline to the existing Ardiya outflow channel. A new pumping station is also part of the associated works.

ARDIYA PRE-TREATMENT PLANT

More than ten pipelines feed wastewater to the Ardiya plant inlet from Kuwait City and the surrounding area. Four parallel lines of 6mm step screens remove coarse particles and an aerated grit chamber excludes sand and grit down to a particle size of 0.2mm. Two 20,000m³ circular buffer tanks balance the influent variation, which fluctuates between 5,000m³/h and 31,250m³/h, to regulate the flow to a range of 10,000m³/h and 20,000m³/h. Agitators within the buffer tanks maintain a flow velocity greater than 0.3m/s to avoid sedimentation problems.

All the structures are covered and a scrubber system is used to treat the air extracted to help prevent odor nuisance.

The existing pumping station in Ardiya has six parallel pumps, and two additional standby pumps, giving a capacity of 20,000m³/h. To accommodate the 50% higher final flow rate, the system design called for the installation of a further four pumps. In addition, 18 surge vessels have been constructed, each with a volume of 130m³, at the pumping station outlet to protect the new main feed pipeline.

This consists of three parallel ductile iron pipes with a 1.4m nominal diameter, lined sulphate resistant cement and a 500-micron epoxy sealant coat. Two line valve chambers, 13 air vent stations and ten washout chambers are located along the pipe route.

WATER TREATMENT AT SULAIBIYA

The treatment regime has been designed to remove organics, minimize nitrate release, reduce phosphate outflow to overcome scaling in the third array of the RO membranes and smooth flow fluctuations in the secondary effluent ahead of the membranes.

An inflow and distribution chamber receives and mixes the inflow of wastewater with the backwash from ultra-filtration and supernatant from sludge treatment. From here it is distributed to the aeration tanks. There are nine aeration tanks with a total volume of 208,900m³, offering anaerobic, anoxic and aerobic treatment zones.

Process performance is optimized within the aeration tanks to achieve the treatment goals. Part of the activated sludge from the anaerobic zone is transferred to the RAS denitrification chamber to serve as a carbon source. With no available oxygen present, phosphate re-dissolves to be later re-incorporated at an enhanced rate into biomass - the so-called 'luxury uptake' - in the aerobic zones. Although this means that high phosphate concentrations occur when the mixed liquor enters the anoxic zone, it subsequently leads to the requisite phosphate reduction necessary to protect the RO membranes. In addition, nitrified activated sludge is returned into the anoxic zone to keep the nitrate concentration in the aerobic zone low, leading to the lowered levels required in the secondary effluent.

Finally, the mixed liquor flows from the aerobic zone to the nine 52.5m-diameter, 4.8m-deep secondary clarifiers, where it is separated into secondary effluent and RAS.

The flow is balanced by permitting the level within the aeration tanks and secondary clarifiers fluctuations to fluctuate by ± 0.5 m, controlled by flow control chambers down-line of the secondary clarifiers.

Sludge is treated to provide a material suitable for unrestricted agricultural use, requiring it to be dry, have a low organic content and be free of pathogens. Seven gravity belt thickeners and 120 sludge drying beds are used to remove water, while the organic component is reduced by four 8,000m³ aerobic digesters. The resulting product is subsequently stored for more than six months before consignment for use. Designed to recover 85% of the inflow, discharging the remaining 15% to the sea as brine, the UF/RO removes residual pollutants, dissolved solids and pathogens from secondary effluent to yield potable quality water.

The front end of the system comprises five 60µm disc filters and an 8,000m³ secondary effluent basin, which serves as suction and chemical conditioning tank for the UF pumps.

Arranged in 68 skids, each equipped with 32 pressure vessels, the UF plant has a total membrane area of 304,640m². The cross-flow, dead-end membranes will be cleaned by chemical enhanced backwash using a primary acid wash, followed up with chlorine rinse if required.

Filtrate flows into a 6,000m³ basin before being pumped to the RO facility. This comprises 24 first array skids, 12 second array skids and six third array skids, each holding 72 20cm pressure vessels, equipped with seven, 20cm x 1m membrane modules per vessel. The first array is fed by six groups of four pumps with six fully independent sump pumps, the second by six groups of two pumps and the third by six pumps. All of the feed pumps are rated at 780m³/h capacity. The facility is fitted with an in-situ cleaning system.

Six air stripping tower degassifiers remove CO₂ from the permeate and a chlorine dosing facility also form part of the plant.

KEY PLAYERS

The contract was awarded and administered by the Kuwaiti Ministry of Public Works. The main contractor is UDC - jointly owned by the Kharafi Group (75%) and Ionics (25%). The Philipp Holzmann Kharafi Sulaibiya Joint Venture (PHKSJV) was EPC contractor to design and build the complete project. ILF Consulting were responsible for the project design and Ionics Italba for the membrane treatment plant. Kharafi National, in cooperation with United Utilities, will have the 27.5-year O&M contract to run the plant after construction, with Ionics responsible for operating the membrane system over the concession period.

The National Bank of Kuwait (NBK), Gulf Bank and The Bank of Kuwait and the Middle East were the finance arrangers, with NBK acting as the facility agent. ABN Amro were financial adviser to UDC. PKF acted as financial model auditor for the loan arrangers and the design review and technical due diligence was performed by Halcrow.

Legal advice came from Allen & Overy, Shearman & Sterling and Al-Essa, Al-Bader & Partners. Willis and Arab Commercial Enterprises advised on insurance. Camp Dresser & McKee and KEO International Consultants acted as technical advisers and construction managers. Piping and internal cement / epoxy was supplied by Xinxing Ductile Iron Pipes and pipe couplings by Viking Johnson. ITT Industries are responsible for designing, building and commissioning the aeration, pumping and mixing system and Norit are the suppliers of the ultra-filtration membrane technology. WL Delft Hydraulics performed the dynamic hydraulic analysis.

SUCCESS STORY 2

WASTEWATER TREATMENT PLANT, AGADIR - MOROCCO

Today with its population of over 350,000, the rapidly growing Greater Agadir faces need for wastewater treatment and increased demand for water supply. The two main discharges of raw sewage, one into the port area, the other into the bed of the Souss wadi, at a few kilometers of its mouth, become less and less compatible with valuable tourist attraction.

In the Moroccan-French cooperation project, pilot wastewater treatment through dune sand infiltration-percolation is underway at Ben Sergao (a suburb of Agadir). After treatment by anaerobic stabilization pond (chemical oxygen demand, COD, of raw sewage=1,190 mg/L), the pilot wastewater treatment by infiltration-percolation plant treats 1,000 m³/d of highly concentrated effluents in five infiltration basins of 1,500 m² each, consisting of two-meter thick eolian sand. The anaerobic stabilization pond (1,500 m³ for a theoretical residence time of 2 days; depth of the pond: 3-4 m) is used to reduce suspended solids (40-50 %) and organic matter (50-60 %); thus, reducing the surface areas necessary for the infiltration basin. The basin is submerged for 8 hours and stays dry for 16 hours.

The wastewater was infiltrated at the rate of one meter per day. With this process nearly 100 percent of suspended solids and 95 percent of COD are removed, and 85 % of nitrogen is in oxidized forms and 56 % removed. The percolated water will be used in growing tomatoes (a vegetable extensively cultivated in the Agadir region), public gardens, and future golf courses.

Microbiological quality of raw sewage, pond effluent, and percolated water				
	Raw sewage	Pond effluent	Percolated water	Overall removal efficiency
Fecal coliforms, Numbers/100 mL	6x10 ⁶	5x10 ⁵	327	4.26 logs
Fecal streptococci, Numbers/100 mL	2x10 ⁷	1.6x10 ⁶	346	4.78 logs
Nematode eggs, Numbers/L	139	32	0	100 %
Cestode egg, numbers/L	7	18	0	100 %
Total helminths egg, Numbers/L	214	47	0	100 %

4.4.8 Effluent disposal into seawater

4.4.8.1 Introduction

The disposal of wastewater into a receiving water body is the final link in the chain collection – treatment – disposal, whereas the eventual preceding errors and failures are clearly shown by the impact of the treated effluents on the water quality. The disposal system bears all the problems of wrong design and operation of the collection and treatment facilities into the receiving waters. In parallel, a badly designed disposal system deteriorates the achieved results of the previous stages. Wastewater treatment plant and disposal system must be considered as an integral part of the wastewater system, both in engineering and environmental sense.

Wastewater disposal by **submarine outfalls** is based on the processes of initial dilution, wastewater dispersion as well as on the biochemical processes of self-purification in the seawater. The most difficult case is the disposal into **semi-enclosed sea systems** i.e. estuaries and bays, where the dilution of effluents occurs in a limited water mass. In this case, any malfunctions of the system or inadequate treatment level immediately cause ecological and aesthetic problems. The time required for “washing up” totally depends on the hydrodynamic conditions of the seawater (exchange of the total volume of the semi-closed water system with clean water from the open sea). Usually, advanced treatment is needed to overcome any such circumstances.

In cases of effluent discharges into the **open sea**, the favorable hydrodynamic conditions prevailing there allow more flexibility in terms of treatment: in some cases (e.g. disposal into ocean or in oligotrophic seas), a long outfall after primary treatment is adequate. This possibility can be considered for small communities (e.g. < 10000 p.e.).

It should be mentioned, that detailed technical equations and calculations are not contained in this document, they can be found in many technical publications. Here, a general outline of the information needed to execute a technical solution is presented.

4.4.8.2 Environmental characteristics

The parameters or environmental characteristics to be considered or studied for the design of a submarine outfall are the following:

- Topography and bathymetry (charts and maps of adequate scale)
- Bottom materials and morphology
- Openness of the coast
- Activities and sewage discharges in a 20 km sector around the selected outfall siting and sensitive areas in this sector
- Predominant surface currents and winds pattern
- Wastewater flow and contaminant load.

Some additional parameters should also be measured to support the detailed outfall design:

- Continuous current measurements
 - Dispersion coefficients
 - T90 for faecal coliforms and faecal streptococci
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- Temperature profile
- Benthic populations

The extension and detail of the studies to identify and measure these characteristics will depend on the size of the outfall.

Some of the abovementioned parameters are discussed in more details in the following paragraphs.

4.4.8.2.1 Topography and bathymetry

Good and detailed maps and charts of the coast and bottom areas where the outfall is planned are always necessary. Cadastral scales with 1 m contour interval are normally sufficient for the study of the discharge area and the adequate siting of the outfall. It is recommended to carry out a detailed bathymetric profile of the whole outfall length to identify possible sand bars, bottom material, rock outburst or any other factor which could interfere with the construction of the outfall.

4.4.8.2.1.1 Openess of the coast

The openness and morphology of the coast is one of the main characteristics to be considered when siting, designing and calculating a submarine outfall as it defines the renovation capacity. It is not uncommon to find submarine outfalls whose length appears to be sufficient for the efficient disposal of wastewaters into the sea, but because they start from the inner end of enclosed or semi-enclosed areas, the actual effective length is greatly reduced, when the discharge does not reach the open sea and is made inside the semi-enclosed area.

4.4.8.2.1.2 Activities, sensitive areas, discharges

In the sector comprising 20 km around the proposed siting of the submarine outfall, all zones which support activities with water quality objectives and all sensitive areas which could be affected by the discharge should be studied and plotted on appropriate maps. The distance between the discharge point and the line surrounding these zones and areas will be used for the computations concerning the dilution obtained by the outfall. In order to evaluate the degree of saturation in the affected area due to other wastewater discharges, all such discharges should be identified in the 20 km sector around the proposed siting of the outfall.

4.4.8.2.1.3 Predominant currents and winds

Surface current surveys for the design of submarine outfalls should preferably cover different climatic conditions, but must at least include the summer period, when seawater activities are at their highest. Three to four days of surveys are normally sufficient to obtain enough information for the design. The study of wind patterns in the discharge area must complement the result of the field surveys on the surface currents

4.4.8.3 Planning/design of submarine outfalls

There are many studies to be conducted in the marine area where a submarine outfall will be placed, which will give a detailed information about the prevailing conditions at the point of effluent discharge and the prediction of any adverse effects into the marine environment. Besides the assessment of the sea water conditions (see chapter 2.2.), there are some additional issues to be studied, which are important for the design of the outfall. These are:

- Pattern of wastewater discharge through the outfall i.e. flow inside the pipe and diffuser, development and dispersion of a field near the sea surface
- Assessment of the mixing zone at the point of effluent discharge through outfall's diffusers
- Rate of effluent dispersion (rising phase, phases of secondary and tertiary dilution)
- Analysis of density gradients

Main elements and steps of submarine outfall planning and design are:

- Assessment of wastewater flow (estimation of pollution load and flow)
- Site survey information (assessment of mixing characteristics of sea and sea bed conditions)
- Use Area definition including mixing zone characteristics
- Environmental standards determination associated with Use Area
- Definition of land- based treatment schemes (determination of treatment plant characteristics)
- Selection of headworks and outfall site (selection of the optimal locations in accordance with local conditions/requirements and wastewater collection system characteristics);
- Headworks and storm overflow arrangements (integral analysis and selection of the optimal solution)
- Environmental design (degree of treatment, the storm overflow settings, the discharge rate, the discharge location, the degree of initial dilution)
- Outfall and diffusers arrangements
- Hydraulic design (selection of size of outfall, velocity of flow and velocity of discharge at diffuser orifice)
- Environmental impact prediction (considering the most critical situation related to environmental values/water uses)
- Civil engineering design
- Selection of economic options (construction, operation and maintenance costs, and comparison with other disposal alternatives).

There are also some basic design principles to be followed namely:

- Submarine outfalls should always end in open coastal waters, where multiple discharges in the same area do not affect the background levels
 - As initial dilution is essential, every effort should be made to construct the outfalls with the discharge point situated at the longest distance from the areas to protect and to the greatest depth which can be economically reached. Modern pipe-lying
-

techniques make the total length and depth of the outfall less important in the overall cost of the project (e.g. use of plastic pipes)

- The use of diffusers increases the initial dilution at the discharge point: diffusers ports must have a minimum diameter of 10-15 cm, a total combined surface not exceeding 75% of the pipeline cross section and a spacing equal to one fourth of the depth.
- The effective length (distance between the discharge point and the outer border of the 300 m reserve band) should be larger than 1,500 m and the depth of the discharge point should not be smaller than 15 m.
- Design velocity in the pipeline should be around 1 m/s. To prevent the blocking of the diffusers the velocity of the discharge should reach with sufficient frequency 1 m/s, but should not exceed 2 m/s to reduce head losses.
- Pumping should be avoided if sufficient head is available because of the energy and maintenance costs
- Location of outfall's diffusers should consider the bottom topography. An additional requirement is that this location should secure that even strong on-shore winds and resulting currents would take sufficiently long to move the wastewater field into near-shore waters, so that any water quality criteria would be met.

5 ENVIRONMENTAL IMPACT ASSESSMENT OF WASTEWATER MANAGEMENT FACILITIES

5.1 Introduction

Environmental Impact Assessment (EIA) is a process of identifying, predicting, interpreting and communicating the potential impacts that a proposed activity will have on the environment. With its help, a better understanding of the consequences of a development project can be achieved, where decision makers, stakeholders and the general public are informed about the features of the project and the eventual risks to be caused during its construction and operation. An EIA should be seen as an integral part of the project planning process.

An EIA process is often described as an assessment of how negatively or positively an activity affects various impact indicators, namely parameters, which provide some kind of measurement of the magnitude of an environmental impact in a quantitative or qualitative form. It helps:

- decision makers in making informed decisions on project developments and final project prioritization
- to provide, where possible, relevant and quantitative water quality information so that potential impacts can be avoided or reduced at the project and programme design stage
- to provide a basis for development of management measures to avoid or reduce negative impacts under, and/or after, project implementation.

EIA should form an integral part of multiple resource development planning and feasibility studies for the projects. It should provide a quantified assessment of the physical, biological and related economic and social impacts of proposed projects as well as the likelihood of such impacts occurring. Thus, the impact assessment should accomplish its purpose by providing decision makers with the best quantitative information available regarding intended, as well as unintended, consequences of particular investments and alternatives, the means and costs to manage undesirable effects, and the consequences of taking no action.

An important element in any EIA is the encouragement of public participation in the process. The general public should be given an opportunity to express their views on proposed projects and programs, and procedures should be established for considering these views during the decision making process. In many cases, Non-Governmental Organizations (NGOs) with considerable insight in environmental issues can be identified and may provide valuable contributions to the impact assessment. Public participation can often ease the implementation of projects and programs as a result of the increased feeling of ownership and influence that it produces amongst directly involved users.

In this document the general outline for EIA preparation for wastewater management facilities is presented without conducting a full EIA study. As management facilities are here meant the **treatment installations** and **the submarine outfalls**.

5.2 Content of an EIA study

The operational functions of EIA are to provide the necessary background for:

- approval or rejection of wastewater discharge permit applications
- inclusion of operation conditions in wastewater discharge permits
- inclusion of water quality consequences in the final prioritization of development projects (made by authorities at different levels)
- developing modifications in the technical design of development projects with the aim of protecting water resources.

An EIA study usually contains the following main subjects:

- description of the project and of the activities it is likely to generate
- description and evaluation of the site and its surroundings
- reasons for selecting the proposed site and technology to be applied
- identification and assessment of anticipated or forecasted negative and positive impacts on the environmental quality as a consequence of the project implementation
- description of measures proposed for eliminating, minimizing or mitigating the adverse impacts.

An EIA must be performed by a multidisciplinary team. For wastewater management facilities at least an environmental/sanitary engineer and a marine biologist/scientist should be part of the team.

5.3 Guidelines for EIA preparation for wastewater management facilities

Within the activities of the Mediterranean Action Plan of UNEP (UNEP/MAP), specific guidelines are prepared, which are simple, comprehensive and understandable. They can be quoted by applicants as well as by environmental authorities as a general framework to be followed for the preparation of the detailed EIA studies.

5.3.1 EIA for a sewage treatment plant

5.3.1.1 Description of the proposed project

The proposed treatment plant should be described accompanied by plans including the following:

- types of sewage to be treated (municipal, industrial, agricultural)
 - number of inhabitants to be served by the plant
 - quantity of sewage (m³/day)
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- quality of sewage to be treated (parameters)
- treatment method
- layout of the plant
- disposal/use of effluents (e.g. in agriculture, discharge into the sea, etc.)
- description of the recipient body (open sea, bay, etc.)
- sludge quality (parameters) and quantity
- method of sludge treatment and disposal
- chemical, physical and bacteriological characteristics of effluents (i.e. SS, pH, turbidity, BOD₅, COD, N, phosphates, oil, heavy metals)

5.3.1.2 Description of the environment

a) Physical site characteristics:

- site location on a map

b) Climatological and meteorological conditions:

- basic meteorological data (e.g. wind direction and velocity, average annual rainfall)
- special climatic conditions such as storms, inversions, trapping, etc.
- existing sources of air pollution especially of particulates and odors

c) Geological and hydrological conditions:

- geological structure of proposed area including hydrology and aquifers
- existing uses and quality of water bodies around the proposed site

d) Present land use of the site and its surroundings

e) Characteristics of recipient water body:

- sea circulation, thermocline, thermohaline structure, dissolved oxygen and nutrients concentration, microbial pollution, fishing grounds, aquaculture sites, marine habitats

f) Existence of endemic waterborne diseases

5.3.1.3 Identification of possible impacts

An assessment of anticipated or forecasted impacts, using acceptable standards whenever possible, of short-term impacts associated with the activities related to the construction of the plant and long-term impacts related to the operation of the treatment plant should be given including the following:

- odors and air pollution from the plant and from the disposal of effluents and sludge
- infiltration of sewage into top-soil, aquifer or water supply systems and impacts on drinking water quality
- mosquito breeding and diseases transmitted by mosquitos

- pollution of water bodies (rivers, lakes, sea) by effluents and impacts on bathing water quality
- flora and fauna
- fruit and vegetables safety if land disposal of effluents or sludge is applied
- noise levels around plant and its sources
- disposal of sludge and other wastes
- property de-valuation
- impacts on touristic and recreational areas such as nature reserves, forests, parks, monuments, sport centers, beaches
- possible emergencies and plant failures, frequency at which they may occur and possible consequences.

5.3.1.4 Proposed measures to prevent, reduce or mitigate the negative effects

This section should describe all measures - technical, legal, social, economic or other – to prevent, reduce or mitigate the negative effects of the proposed sewage treatment plant. Additionally it should describe measures for monitoring the effects on a long-term basis, including data collection and analysis as well as the enforcement procedures required to ensure the implementation of the measures.

5.3.2 EIA for a submarine outfall

5.3.2.1 Description of the proposed project

a) The outfall:

- length of pipe of the outfall, diameter, depth, pipe material
- pipe laying method (on seabed, buried in seabed)
- method to control corrosion
- method to protect from trawls and anchoring
- diffuser length, orifices, configuration and diameter
- discharge velocity
- primary and final dilution

b) The effluents:

- effluent characteristics, i.e. quantity, degree of treatment, physical, chemical and bacteriological composition, seasonal variations
- T90 measurements

5.3.2.2 Description of the environment

A description of the environment of the site where the proposed outfall will be placed should be given including the following:

a) Physical site characteristics:

- on-shore topographic and off-shore bathymetric map of the site and its surroundings (scale 1: 5000) covering at least 2 km of the coast and appropriate distance from waterline off-shore and 200 m from the waterline inland
- geological and geophysical conditions at outfall site including rock outcrops on- and off-shore, sedimentological conditions and cliff stability

b) Hydrographic and meteorological information:

- surface and subsurface currents under various tidal, density and weather conditions
- current at depth of effluent disposal
- turbulence
- existence and characteristics of thermocline
- seawater temperature and salinity and their variation with depth
- wind velocities and intensity
- waves
- oxygen and nutrients concentration
- water color and turbidity

c) Biological conditions:

- status of benthic communities on various bottom substrates
- microbial pollution
- plankton including plankton bloom

d) Present and future uses of the sea and the beach:

- tourism, recreation, fishing, aquaculture
- shellfish breeding

e) Ambient quality standards

5.3.2.3 Identification of possible impacts

An assessment of anticipated or forecasted impacts, using acceptable standards whenever possible, should be given including the following:

a) Impacts of construction from:

- *earthworks*
- *road access*
- *noise of equipment*

b) Impacts of operation on:

- *flora and fauna*
- *seawater temperature*
- *bacteria concentration*
- *oxygen and nutrients concentration*

- *water turbidity and color*

c) Impacts on other present and potential land uses on- and off-shore:

- *recreation activities (incl. bathing waters and beaches)*
- *fishing grounds especially in relation to shellfish*

d) Expected impacts on the reduction of gastro-enteric diseases

5.3.2.4 Proposed measures to prevent, reduce or mitigate the negative effects

This section should describe all measures - technical, legal, social, economic or other – to prevent, reduce or mitigate the negative effects of the proposed sewage treatment plant. Additionally it should describe measures for monitoring the effects on a long-term basis, including data collection and analysis as well as the enforcement procedures required to ensure the implementation of the measures.

6 MONITORING OF EFFLUENTS AND OF WATER BODIES

6.1 Introduction

Monitoring of effluents from wastewater management facilities is an integral part of the whole technical solution adopted to solve an existing water pollution problem in an area. It cannot be limited at effluents monitoring only, it has also to deal with the maintenance of the receiving waters' quality, which is the main and final pre-requisite from the very beginning, namely to keep the sustainable use of water resources despite the existence of nearby pollution sources and the discharge of wastewaters into them.

In setting up an effective monitoring program, a harmonized coordination of many institutions is required, in order to ensure the best possible use of existing resources and equipment. In doing so, a good knowledge of the capacities and capabilities of the existing institutional infrastructure and of the needs for improvement is the basis for the design of the program. In this chapter, the involvement of the relevant authorities is described as well as the basic elements of a comprehensive monitoring program. Finally, a description of the needs of the general public on information about the monitoring results is added.

6.2 Role of the authorities

Many countries have extensive central government agencies, while regional and especially local levels have minimal experience and capabilities. Thus, institutional strengthening must begin with adjusting existing structures and capacities. The national institutional framework must be integrated to ensure that central, regional, and local agencies are aware of and committed to the fact that coordination and cooperation are essential when addressing wastewater issues.

Before modifying institutional arrangements, existing wastewater discharge system and institutional framework must be identified and their strengths and weaknesses assessed. The assessment should examine the system and agencies already in place, their organizational structure, roles, responsibilities, authorities, and the strengths, shortcomings, gaps and/or overlaps in all these aspects.

Based on such an assessment, initial needs for improvement can be flagged. With this vital background information, an overall strategy for the reform of institutional arrangements can be formulated and the subsequent planning phase can start in an efficient and targeted way. An initial needs assessment will also clearly illustrate that any strategy towards reform of the institutional arrangements will have to be a long-term commitment.

General trend in today's national regulation systems is to clearly identify and separate the roles of water resources management, regulation and operation. The central

government institutions have to properly distribute responsibilities among different national Ministries and/or regional and local authorities, necessary for successful implementation of the strategy for sustainable water resources management. The key questions, which should be addressed, are:

- Decide on the “lead” institution for implementing the strategy, as well as for ensuring the cooperation and decision-making process in case of other ministries being involved. In general, Ministries that will be involved are the Ministry of the Environment (water quality standards, emission limit values), Ministry of Health (drinking water, use of treated wastewater), Ministry of Agriculture and Forestry (use of sludge) Ministry of Industry (emission control of industrial discharges) and Ministry of Foreign Affairs (trans-boundary pollution)
- Decide on the distribution of responsibilities (legislation, implementation) among national, regional and local bodies
- Arrange for the involvement of other public bodies and agencies (environmental agency, water agency, water/environmental inspectorate, etc.)
- Adopt, design and implement a national plan for water protection

The competent **national authorities** are generally responsible for:

- Planning and implementation activities, including setting clear water quality goals and emission limits values, which integrate environmental and economic considerations with the full participation of stakeholders and consideration for community views
- Regulation addressing duplications and gaps in government and sectors responsibility for water and wastewater regulation
- Putting in place clear accountabilities and establishing management for water resources
- Meeting the community’s legitimate demands for input into decision making processes
- Establishing an inspectorate authorized to inspect installations and monitor management practices and water quality against objectives.

The role of **regional and local authorities** in the water sector is important because:

- Modern concept of water management is based on decentralization of river basin, and involves local people as much as possible in the planning and decision making process
 - Needs of the co-operation of regional and local authorities in developing operational objectives, which are also use-related (water for bathing, water for aquaculture, water for drinking water abstraction, water for irrigation, etc.)
 - The provision of water and wastewater services is the responsibility of the regional or local Government
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- The responsibility for the construction of water and wastewater treatment plants, water pipelines and sewer networks.

6.3 Sampling and monitoring

The monitoring of the quality of the receiving waters and of the effluents is a crucial part of a **water pollution control authority**, which, in many cases, has or will be established, at least at regional level, to perform entirely this work. These authorities, besides the related personnel, should be equipped with the necessary chemical, biological and microbiological laboratories, in order to perform their tasks. In many cases it is easier and cheaper to cooperate with laboratories of universities, institutions accredited to perform the analyses, however, on-spot analysis should be undertaken by the authorities/agencies themselves.

Sampling and monitoring of the environmental media (receiving water bodies) and of effluents are needed to determine whether:

- the predicted effluent quality is achieved
- the level of impact or change caused by the management system is as predicted
- the agreed environmental values are met.

This information should be a major input into strategic options for water pollution control at regional and central level, since it will reveal any malfunctioning and drawbacks related to the operation and, in some cases, to the design of wastewater management facilities, so that new strategies or modification of existing options can be introduced.

6.3.1 Environmental monitoring

A sampling program for the environment is usually based on the output from a detailed site study and consideration of the discharge's nature and volume. However, relevant regulations require a certain sampling program to be implemented and information to be delivered. A good example of a full monitoring program is contained in the EU Water Framework Directive, which describes in great detail a monitoring program to be implemented, including:

1. Surveillance monitoring for:
 - supplementing and validation of the impact assessment procedure
 - an efficient and effective design of the future monitoring program
 - the assessment of long-term changes in natural conditions
 - the assessment of long-term changes due to widespread anthropogenic activities.
2. Operational monitoring undertaken in order to:
 - establish the status of those water bodies identified as being at risk of failing to meet their environmental objectives
 - assess any changes in the status of such bodies resulting from the programs of measures.
3. Investigative monitoring carried out:
 - where the reasons for any deviation are known

- where surveillance monitoring indicates that the objectives set for a body of water are not likely to be achieved
- to ascertain the magnitude and impact of accidental pollution.

Monitoring of environmental changes related to effluent discharges is complex and expensive. The frequency and scope of monitoring need to be considered on a case-by-case basis, and have to be implemented in accordance with relevant national and international standards (ISO, EN, etc.) and requirements.

Each country should design and implement its own monitoring program in accordance with the national regulations and international obligations. A broad range of aspects needs to be considered when assessing the impact on the environment, such as:

a) In cases of effluent discharges into water:

- the current background quality of the water body status of ecosystems, both pre and post discharge
- modeling of effects on the receiving environment, including the effects from all other discharges to the water
- sampling the water in and beyond the mixing zone and sampling of sediments and fauna
- establishing control sites beyond the influence of the discharge to identify any changes
- biological monitoring

b) In cases of land disposal:

- soil type
- vegetation cover
- potential for runoff
- evaluating the impact of the discharge on soil quality
- sampling of groundwater, nearby surface waters, soil and crops

c) For products based on wastewater and sludge reuse:

- reused effluent/sludge application
- vegetation production and use
- mobility of pollutants from land sources
- prioritization of sources and causes
- possible impacts on environment and consumers of food produced by reuse-amount of toxic, persistent or bio-accumulative materials in effluent, sludge and products
- health effects and risks

6.3.2 Effluent monitoring

Competent authorities or appropriate bodies shall monitor:

- discharges from urban wastewater treatment plants to verify compliance with the requirements
- amounts and composition of sludge disposed in the surface waters.

Monitoring of effluent quality may be also undertaken to:

- assess treatment performance
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- assess self-monitoring and reporting program
- meet regulatory/permit requirements
- detect changes in effluent quality that could have an impact on the environment
- provide data for long-term planning, and confirm the design criteria
- meet research needs.

The nature and frequency of sampling required depends on a large number of factors, such as:

- sensitivity of the environment
- regulatory requirements
- nature of the treatment process
- risk to the environment
- quality of the environment
- variability of the flow (daily and seasonal)
- composition and variability of the inflow's industrial waste component, if any
- reliability of the treatment process
- competence of the operating staff to conduct self-monitoring
- effectiveness of the plan's maintenance and supervision
- remoteness of the plant.

Because monitoring is an expensive task, it is necessary to achieve optimization. It is recommended that sampling should be made at two levels:

- a small number of critical parameters related to the treatment process and impact on the environment
- a broad range of parameters covering all those with identified potential for impact on environment.

Sampling should be more frequent in case of larger treatment plants, where there may be significant impacts on the environment, or in case of effluent discharges into sensitive areas. Composite sampling is more suitable for large plants and in cases when it is necessary to estimate the total load and peak pollution load to the environment.

Potential variability of the quality of effluent may influence sampling frequency. It depends on the type of treatment processes: processes with longer detention time (e.g. lagoons) are less likely to have sudden changes in effluent quality than the plants with short detention time (e.g. conventional activated sludge process with mechanical aeration).

A certain **monitoring cycle** should be planned, in order to develop an effective monitoring program, which will provide valuable information to decision makers, in order to either assess whether wastewater management facilities comply with existing legislation or to re-design the various amelioration measures needed to improve the situation. Therefore the monitoring cycle is a guiding principle: the process of monitoring and assessment should be seen as a sequence of related activities that begin with the definition of information needs and ends with the use of information product. Successive activities in this chain should be specified and designed on the basis of the required information product as well as on the preceding part of the chain.

Elements of the monitoring cycle are:

1. Water management goals and needs (water quality objectives and criteria, desirable water uses)
2. Information needs for the management (how frequently failures occur, which parts of the facilities do not comply with quality standards, extent of failures, etc.)
3. Monitoring strategy to gather information
4. Monitoring network design and optimization
5. Sampling (random, on-site, composite)
6. Laboratory analysis
7. Data handling
8. Data analysis, validation and approval
9. Reporting
10. Information utilization by management

6.4 Enforcement

In order to achieve the water quality objectives, the measures put in place must be properly implemented and enforced. This can be achieved by developing a suitable regulatory regime with adequate resources to implement and enforce the law. Regulation in this sector, in general, involves the following activities:

- authorization and/or permitting
- monitoring, inspection and enforcement, auditing
- data collection and reporting.

The principal tasks related to authorization and permitting are:

- issuing permits for discharges to water and sea, including quantity and quality of the discharge, setting emission limit values and ensuring compliance with the water quality
- objectives issuing permits for the abstraction and use of water and sea, bearing in mind the principle of long-term balance between abstraction and natural recharge, environmental needs and competitive uses of water/sea body.

In setting conditions, the competent authority may have to take account of the interests of other statutory bodies and others who may be affected by the discharge or activity through consultation.

6.5 Public information

6.5.1 Introduction

Progress and results achieved from the whole set of the monitoring program should also be prepared in a comprehensive set of information and regularly published aiming at the information of the general public, Non-Governmental Organizations

(NGOs), etc. The objective of this function will be to stimulate public awareness and sensitivity of all those involved in environmental protection including donors, the scientific community and key players in the decision making process (economical, industrial associations, NGOs, etc.), in order to faster accelerate the mechanisms needed to promote the necessary measures. In response to that, decision makers could easier introduce those structural changes needed for further development of the program, e.g. harder legislation, re-location of industries, additional financial resources, if the society is well informed about the scope and the benefits of the envisaged measures.

In order to fulfill these requirements, the information to be provided has to be condensed and attractive by avoiding too many details and technical/scientific conclusions. Therefore it has to contain some technical information from the monitoring results (e.g. which plants failed to meet the set standards) but also some financial aspects, as well as a short description of the problems encountered and proposals for additional measures.

6.5.2 Information required for the public

a) Technical aspects

- max. permissible total loads of priority pollutants (according to set effluent standards)
- sectors causing pollutant release (number of plants)
- existing situation concerning municipal sewage management
- description of programs and projects in progress

b) Financial aspects

- total budget foreseen and % spent so far for each wastewater management facility in the area concerned
- time table for work completion

c) Problems – proposals

- affected water recipients
- description of the existing legislative framework (authorization/permits, values of effluent standards)
- explanation of technical and/or financial difficulties encountered during the execution of the relevant projects
- proposals for action

A summary of the necessary reporting issues is presented in Table 6.1.

Table 6.1 Elements of public information

Component	Activity	Indicator
Technical aspects	Total loads of pollutants released	tons/year in each administrative region and on national level
		% of deviation from max. permissible quantities (according to permits)
	Sectors causing major pollution problems	names of sectors and area concerned
	Programs/ projects in progress	environmental benefits expected, % of completion
Financial aspects	Budget, time table of projects	total budget for each one, time table for completion
Problems – proposals	Legislative framework	description of authorization procedures/standards
	Technical/ financial difficulties	description of relevant projects
	Proposals	revised budgets and time tables, additional projects

7 ECONOMIC INSTRUMENTS AND COST RECOVERY MECHANISMS

7.1 Introduction

The use of economic instruments is part of a programme of measures for sustainable water quality management. The investment level, with its operational and maintenance costs, determines the costs that need to be recovered through a combination of tariffs or taxes. Cost recovery in turn determines the service level that can be provided and the associated water quality objectives that can be realized. Recognizing different needs of different users and selecting the technical and institutional solution for which those users are willing and able to pay are prerequisites for optimizing revenue.

Traditionally, investments for wastewater management infrastructure have been met solely from public grants financing, foreign aid, or multilateral lending. The largest funding sources are local, originating from governments (who obtain funds through various local and national fiscal flows), users (paying for their own on-site systems or paying bills to official service providers) and local banks and donors (including private voluntary contributions).

The principles of recovery of the costs of water services, including environmental and resources costs associated with damage or negative impact on the aquatic environment, have to be taken into account in accordance with polluter-pays and user-pays principle. This means that anyone whose action pollutes or adversely affects the environment should pay the cost of the remedial action. Concerning municipal wastewater management, this is the case of industries, which discharge un-treated wastes into the municipal sewer eventually causing adverse effects on sewer's and plant's quality (polluter pays principle). Concerning households they pay the water supply as well as the wastewater management system (user pays principle).

Designing and enforcing cost recovery mechanisms is a complex process. It requires arrangements (technical, institutional, legal, and financial) for a good monitoring system, including regulations and legislation on receiving water quality levels and emission standards. An efficient revenue collection system should be in place, including capabilities and capacity to assess the right tariffs, to implement appropriate billing systems and to enforce fines if needed. And lastly, polluters need to be willing and able to change their behavior. For efficient revenue collection it is better to advocate that users are required to pay for a service delivered to them rather than to impose a penalty for disposing waste.

The application of economic tools cannot currently replace the regulatory approach to combat pollution. It should be seen as part of an integrated system of incentives and regulations where price driven forces such as costs for water use promote preventive measures in households, industries and thus reduce the wastewater quantities and relevant costs for treatment and disposal. Market based instruments rely upon market factors to change the relative price of goods and services, which in turn modifies the

behaviour of public and private polluters so that environmental protection or improvements can be achieved.

7.2 Cost recovery instruments

The main instruments of cost recovery are:

a) Consumption-based user charges:

User charges are levied upon discharge of wastewater into the sewerage based on volume and/or characteristics of the effluent. The volume of discharged wastewater is directly related to consumption of potable water. Consequently, the tariff is usually collected as a surcharge on the water consumption bill.

b) Effluent charges:

Effluent charges are based on actual quantities and/or pollution loads of effluent i.e. on a fixed amount per household, or, with regard to an industry, on a proxy based on verifiable information about the industry (production, number of employees, etc.). They need to be set at a realistic level to encourage reduction in effluent production.

c) Discharge permits:

A responsible authority sets maximum limits on total allowable emissions of a pollutant to a sewer or to surface water. In discharge permits, charges or levies can be incorporated for cost recovery purposes. A permit system requires elaborate monitoring of effluent flows and quality. High costs for discharge permits may on the one hand encourage industries to pre-treat their wastewater flows to ensure that they are suitable for discharge to surface waters. However, high tariffs may also induce illegal discharges outside of the wastewater system.

d) Tradable permits:

The responsible authority sets a limit on the total allowed emissions of pollution and allocates this amongst the sources of pollution by issuing permits to emit a stipulated amount over a specified period of time. After the initial distribution, permits can be bought or sold. Trade can be external, between different organisations, or internal, between different installations within the same organization (restricted use in accordance with specific situation).

e) Subsidies:

Subsidies include tax incentives, tax credits, grants and low-interest loans.

f) Deposit-refund systems:

Customers pay a surcharge when buying a potentially polluting product. On returning to an approved centre for recycling or disposal, their deposit is returned. This is particularly the case for recyclable materials (e.g. paper, glass, etc.) and does not apply in the wastewater management cycle.

g) Enforcement incentives:

These are penalties to induce polluters to comply with environmental standards or regulations. They include fines (for exceeding limits), performance bonds (payments

to regulatory authorities before a potentially polluting activity is undertaken, which is returned when the correct regulatory levels are met), and liability assignment (where polluters are made liable for any environmental damage they cause).

7.3 Capital (investment) – operational costs

Any wastewater programme needs to address financing and cost recovery for sustainable sanitation schemes and ensure equity as much as possible. Unfortunately, users are willing to pay only for what they see as a benefit or priority, so that they would like to pay for water supply, in the last decades, however, a tendency of acceptance of wastewater management charges has occurred. Usually it is not sufficient to pay the full cost of the systems (collection, treatment and disposal).

The concept of “full economic cost recovery” can and will provide an adequate signal only when the following are met:

- There is a clear relationship between the water use (pollution) on one hand and the costs of providing the necessary services and environmental cost on the other and it is possible to put monetary value on these costs
- The institutional framework enables Governments to charge the polluter and the consumer and there is a political “willingness to charge”, which again depends strongly on the social and economic context and the public “willingness to pay”.

The estimation of costs relevant to the installation and operation of systems for pollution reduction is totally depending on local and site-specific considerations, so that no comparison can be made between regions and countries. Thus, estimates of costs for similar facilities and control techniques often vary widely reflecting not only the local conditions but also alternative technical/economic assumptions and methodological differences.

7.3.1 Investment costs

For the calculation of investment costs the following factors should be considered:

- expenditure on the construction or acquisition of equipment (equipment/supplies, engineering, labor and supervision, instrumentation, piping, safety/sanitary facilities, etc.)
- expenditure on the construction/acquisition of buildings needed for equipment installation/ operation (excavations, building/storage facilities, roads, etc.)
- expenditure on the acquisition of land needed or value of land already owned
- expenditure on necessary production modifications
- start-up running costs (raw materials, chemicals, labor, energy costs, etc.)
- cost of money (interest rate) over the project’s construction/installation period

7.3.2 Operational costs

The factors determining the annual operating costs, a cost item sometimes underestimated in decision making, can be summarized as follows:

- total personnel costs required for system operation
 - maintenance/repair
 - systems administration/management (communication, transportation, expenses connected with management activities)
 - consumables (raw materials, chemicals, energy, water)
 - monitoring/laboratory costs
 - annual cost of interest of the overall investment
 - taxes and insurance
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8 CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the contents of these Guidelines through a number of key issues with recommendations for sewage management to protect the marine environment.

Issue 1

A comprehensive approach to urban sewage management is necessary in order to maintain the environmental integrity and the economic functions of coastal areas.

Discussion

The no-action alternative imposes great costs on the present and, even more so, on the future generations. Water pollution has many impacts in rivers and lakes, in groundwater, and in coastal waters. Especially the poor suffer from lack of proper sanitation, a challenge for many cities and towns in developing countries. But both industrialized and developing nations still face an unfinished agenda to cope with the long-term effects of specific pollutants, notably nutrients (causing eutrophication), pathogenic micro-organisms, and toxic chemicals and heavy metals. A multi-targeted strategy is required.

Recommendations

- Promote studies that allow quantifying the economic impact of pollution and disseminating these results.
- Use such information to decide on the priorities for investment and for cleanup programs.
- Set up long-term, targeted, and realistic policies and strategies, that acknowledge the interrelationships between the various origins and impacts of water pollution in the urban-coastal context. Some of the impacts have a large geographical scale and need internalization of the costs/responsibilities (*e.g.* eutrophication), whereas other types of pollution are more local (*e.g.* requiring on-site sanitation).

Issue 2

The task to collect and treat all the urban wastewater requires prioritization and a phased approach.

Discussion

The solution to collect and centrally treat all urban wastewaters can be too expensive. The cities and communities, especially in developing countries, cannot hope to be able to pay for this entire infrastructure within a short period of time.

Recommendations

- Prioritization is required aiming at the minimization of the current and the future environmental damage with a few carefully selected investments and programs, in a phased approach. Appropriate standards must be imposed that are feasible for the local condition instead of borrowing standards from other countries.
- There is no one magic technology, or no technology that is equally suited for all regions, climates and socio-economic conditions. A variety of technological options and managerial approaches exist. A strategic sanitation approach is warranted applying a mix of options, each appropriate and optimal for a different zone and/or region.

Issue 3

Apply technologies and approaches that minimize or prevent pollution. High cost of wastewater management asks for a very careful search for low-cost and more sustainable technologies and approaches.

Discussion

Conventional “end-of-pipe” technologies and strategies are expensive and unsustainable. Additionally, they do not cut costs by stimulating, over time, waste minimization.

Recommendations

- Although end-of-pipe technologies have their place in strategies, introduce as much as possible strategies and incentives that target waste minimization and prevention.
- Apply novel, more cost-effective technologies such as lagoons, natural systems, anaerobic treatment and re-use schemes.
- Apply land-use and institutional approaches to minimize the amount of waste produced and to be treated.
- Industrial and trade effluents often disturb proper treatment and reuse of domestic wastewater. Therefore, adapt land-use policies and financial and other regulation to promote relocation of industries to special estates with dedicated treatment facilities, application of recycling methods and of best available technologies.
- There is often lack of information of the short-term and long-term impacts of effluents on the water resource. Perform water quality monitoring and environmental impact studies.
- The development of new concepts should be stimulated. While all technologies will be subject to major developments over the coming years, the further development of novel and cost effective technologies, such as anaerobic treatment, lagoons, natural systems and re-use schemes requires special attention.
- The process of technology selection should be studied more systematically because comparative data for different technologies operating under similar conditions are not available. This refers not only to treatment performance data, but also to investment costs, operational costs, energy requirements, environmental impacts, etc.

Issue 4

Financial sustainability of the infrastructure remains a major concern.

Discussion

Too many investments and efforts do not lead to truly functional programs because they are sometimes financially not viable. This is the main “limiting factor” to achieve substantial improvement.

Recommendations

- The principles “water user pays” and “polluter pays” are the key guidelines.
 - To best prioritize investments in a river basin, and in cases where pollution mitigation costs exceed local affordability (the “normal” situation in developing countries), all those who are stakeholders and stand to gain from the water quality improvement should contribute financially. A pollution fee based on “river basin (or regional) solidarity” is an effective instrument to allow investment in priority schemes with high cost-effectiveness that maximally benefit the whole basin or region.
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- Finance raised from water use charges or pollution fees should not be considered as taxes and enter the national budget, but should be earmarked for water quality management initiatives in the river basin or region that generated the funds, such as co-financing wastewater treatment facilities.
- Determine what truly works for which countries and for which situations. It is better to apply something that works even if not perfectly, than something that is perfect but does not work.

Issue 5

Central Government should act and organize itself as a facilitator not as a provider of services.

Discussion

Weak institutions in public administration can cause failures so far to "get things started". This is caused by poor institutional and professional capacities and poor public governance and accountability.

National Governments, because of their distance to the local problems, are not suited to implement physical programs. These should be decentralized to local initiatives, notably co-operative associations of municipalities and/or provinces/states, regional environmental or river basin agencies; community-based organizations in peri-urban zones and private and NGO initiatives.

Recommendations

- National Government must recognize that it holds the responsibility and authority to start an initiative.
- It must set the institutional environment that will allow local government and regional and river basin agencies to start with consistent programs. This environment includes enacting legal and regulatory instructions for this purpose, developing national policies and strategies in co-operation with local governments and other stakeholders, setting up appropriate organizations that can complement local government initiatives and co-financing schemes and infrastructure that have a high cost-effectiveness and priority.
- As the origin of pollution is always "local", the solution to it will always be local as well. Therefore, national Government has a responsibility to assist local and regional initiatives in combating pollution.
- The mandate of local governments and environmental agencies must be such that they can be held accountable with respect to their performance in reducing pollution. Awareness in civil society needs to be strengthened, in order to make citizens and their representatives capable of fulfilling the task of supervising and controlling these organizations.

Issue 6

Private sector participation (PSP) is an important new tool to assist local governments in their task of financing and operating the infrastructure for wastewater management.

Discussion

PSP can help to improve managerial performance, find synergies and economies of scale and get access to investment capital.

Recommendations

- Review the regulatory and legal framework that would impede the introduction of PSP arrangements. Carefully devise the requirements and options for such arrangement, which should be compatible with the country's economic, social and

political situation. Promulgate regulations and laws to facilitate that local governments contract out management and operations of utilities or award lease and concession contracts to private partners.

- Pilot PSP initiatives and learn from the experience.
- Ensure appropriate “re-regulation” to avoid monopolistic behavior.
- Irrespective of whether the wastewater utility is managed by a private firm or public entity, set up regulation to measure its performance against international benchmark and consumer satisfaction.

Issue 7

Develop an effective system to regulate pollution.

Discussion

Households, industries and municipalities have many arguments why they should not take action in pollution abatement. Water pollution control is pre-eminently an activity of many actors who must be willing to co-operate and contribute their effort to the overall result. Yet, traditional top-down method, administrative regulation and instructions often are ineffective.

Recommendations

- Apply “stick and carrot” regulation. The stick represents the restrictive rules including penalties for the offenders of the rules. However, to make this approach more effective, add positive incentives, such as arrangements to co-finance constructive initiatives and awards for outperforming industries and local governments.
- Introduce market-based instruments that allow more flexibility to polluters to invest in pollution control. Use them in conjunction with administrative regulation. This combination, if applied in the proper circumstances, is often more effective than administrative regulation alone.
- Arrange for mechanisms that allow civil society and its representatives (such as consumer associations) to hold polluting entities, whether they are private or public, accountable.

Issue 8

No pollution mitigation scheme can succeed without the commitment of the citizens.

Discussion

Citizens are both (part of the) problem and the solution. They are important polluters through their domestic sewage and through their economic development. At the same time, as they appreciate a clean and healthy environment, they can exert pressure on polluters to clean up their act.

Recommendations

- Invest in awareness creation among citizens regarding their double role as polluter and as responsible citizen.
 - Develop commitment to a clean environment and “river basin solidarity” and demonstrate that “win-win” situations exist when all polluters agree to cooperate in pollution mitigation. The equity principle in terms of environmental quality is an important driving force. Strengthen the perception that sanitation brings profits in the long term only but imposes costs on the short term.
 - Use cross-subsidies in these situations, to compensate the substantial externalities.
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- Bring decision-making to the lowest appropriate administrative level and ensure that local communities receive financial powers to participate in local or regional initiatives to operate and manage their part of the infrastructure.
- Ensure that citizens receive a decent “sewage and drainage service” in return for their financial contribution.

Issue 9

Institutional capacities are weak in most developing countries. At the same time, however, the abatement of several types of pollution has not yet been perfectly resolved by industrialized countries either.

Recommendations

- Attach adequate importance to training and education of the sector professionals, as well as the representatives of civil society and industry.
- Review how these capacities are used to their maximum potential, by the organizations responsible for pollution mitigation.
- Develop a long-term institutional review and capacity building strategy, aiming at individuals, legal and regulatory frameworks and organizations.
- Develop dedicated networks of multi-disciplinary teams of experts in Government, industry and civil society.
- Make sure that these networks assist to identify the problems to be solved and that they assist to draw in experience from other countries in the region.

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10 APPENDICES

10.1 APPENDIX I

PROTOCOL FOR THE PROTECTION OF THE MARINE ENVIRONMENT AGAINST POLLUTION FROM LAND BASED SOURCES

THE CONTRACTING STATES

BEING PARTIES to the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution;

RECOGNIZING the danger posed to the marine environment and to human health by pollution from land-based sources and the serious problems resulting therefrom in coastal waters of many Contracting States, principally due to the release of untreated, insufficiently treated and/or inadequately disposed of domestic or industrial discharges;

NOTING that existing measures to prevent, abate and combat pollution caused by discharges from land-based sources need to be strengthened on a national and a regional basis;

BEING AWARE of Articles 194, 207, 212 and 213 of the United Nations Convention on the Law of the Sea (1982); and the Montreal Guidelines for the Protection of the Marine Environment against Pollution from Land-Based Sources (1985); and

DESIROUS to strengthen the implementation of Article III, paragraph (b) and Article VI of the Convention;

HAVE AGREED AS FOLLOWS:*

ARTICLE I

DEFINITIONS

For the purpose of this Protocol:

1. "Combined Treatment" means common treatment of industrial effluents along with domestic sewage;

* A Meeting of the Plenipotentiaries was held in Kuwait on 21 February 1990 for signing the Protocol concerning the Protection of the Marine Environment against pollution from Land-Based Sources.

2. "Competent State Authority" means the Authority designated by the Contracting State for the purpose of this Protocol;
3. "Contracting State" means any State which has become a party to this Protocol;
4. "Convention" means the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution;
5. "Council" means the organ of the Organization as referred to in subparagraph (i) of paragraph (b) of Article XVI of the convention;
6. "Freshwater Limit" means the place in watercourses where, at low tide and in a period of low freshwater flow, there is an appreciable increase in salinity due to the presence of sea-water;
7. "Joint Pretreatment/Treatment" means common pretreatment/treatment of the effluent from more than one industrial source;
8. "Land-based Sources" means municipal, industrial or agricultural sources, both fixed and mobile on land, discharges from which reach the Marine Environment, as outlined in Article III of this Protocol;
9. "Marine Environment" means the Protocol Area as defined in Article II of this Protocol;
10. "Organization" means the Regional Organization for the Protection of the Marine Environment established in accordance with Article XVI of the convention;
11. "Pollution" means "Marine Pollution" as defined in paragraph (a) of Article 1 of the Convention;

ARTICLE II AREA OF APPLICATION

The area to which this Protocol applies (hereinafter referred to as the "Protocol Area") shall be the Sea Area as defined in Article II, paragraph (a) of the Convention, together with the waters on the landward side of the baselines from which the breadth of the territorial sea of the Contracting States is measured and extending, in the case of watercourses, up to the freshwater limit and including intertidal zones and salt-water marshes communicating with the sea.

ARTICLE III SOURCES OF POLLUTION

This Protocol shall apply to discharges reaching the Protocol Area from land-based sources within the territories of the Contracting States, in particular:

- a) from outfalls and pipelines discharging into the sea;
- b) through rivers, canals or other watercourses, including underground watercourses;
- c) from fixed or mobile offshore facilities serving purposes other than exploration and exploitation of the sea bed, its subsoil and the continental shelf; and
- d) from any other land-based sources situated within the territories of the Contracting States, whether through water, through the atmosphere or directly from the coast.

ARTICLE IV SOURCE CONTROL

1. The Contracting States undertake to implement the action programs based on source control as outlined in Annex I to this Protocol. To this end, they shall develop and implement, jointly or individually, as appropriate, the necessary programs and measures.
2. The programs and measures and the timetables for their implementation aimed at reducing pollution from land-based sources, shall be fixed by the Contracting States and periodically reviewed and revised, if necessary every two years, in accordance with the provisions of Article XIV of this Protocol.

ARTICLE V JOINT AND/OR COMBINED EFFLUENT TREATMENT

1. The Contracting States in their endeavor not to inhibit the development of new industries, and especially that of small industrial operations, and recognizing the economic and technical difficulties often encountered by such operations in properly treating their effluent individually undertake to implement, to the extent possible, industrial location planning programs as outlined in Annex II to this Protocol. To this end, they shall develop and implement, jointly and/or individually, as appropriate, the necessary programs and measures.
 2. The Regional guidelines and criteria along with programs and measures and the time-tables for their implementation, aimed at reducing pollution from land-based sources through joint and/or combined effluent treatment, shall be
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fixed by the Contracting States and periodically reviewed and revised, if necessary every two years, in accordance with the provisions of Article XIV of this Protocol.

ARTICLE VI
REGIONAL AND LOCAL REGULATIONS/PERMITS FOR
RELEASE OF WASTES

1. As outlined in Annex III to this Protocol, the Contracting States shall progressively develop and adopt, in cooperation with competent Regional and International Organizations as appropriate:
 - a) Regional guidelines, standards or criteria, as appropriate, for the quality of sea-water used for specific purposes that is necessary for the protection of human health, living resources and ecosystems;
 - b) Regional regulations for the waste discharge and/or degree of treatment for all significant types of land-based sources;
 - c) Stricter local regulations for waste discharge and/or degree of treatment for specific sources based on local pollution problems and desirable water usage considerations.

Stricter regulations for specific sources serve the purpose of preserving the quality of seawater required for the intended use. In developing such regulations the local ecological, geographical and physical characteristic, as well as, the level of existing pollution in the Marine Environment shall be taken into consideration.

2. The programs for the implementation of the above measures shall be adopted and shall take into account, for their progressive application, the cost of measures involved, the capacity to modify existing installations, the economic capacity of the Contracting States and their need for sustainable development.
3. Polluters shall be required to obtain a permit to discharge from the Competent State Authorities. Such permits shall allow for review and modification of discharge conditions reflecting the periodic update of regulations.
4. Guidelines, standards or criteria, as well as, regulations, programs and measures shall be developed and adopted in accordance with the provisions of Article XIV of this Protocol and periodically updated, if necessary every two years, to reflect the increasing information through the monitoring program described in Article VII of this Protocol, the changes in the industrial and other human activities and possible advances in Science and the pollution control technologies.

ARTICLE VII
MONITORING AND DATA MANAGEMENT

1. The Contracting States, within the framework of the provisions of Article X of the Convention, shall carry out monitoring activities, if necessary in co-operation with the competent Regional and International Organizations, in order to:
 - a) collect data on natural conditions of the Protocol Area as regards its physical, biological and chemical characteristics;
 - b) collect data on inputs of substances or energy that cause or potentially cause pollution from land-based sources, including information on the distribution of sources and the quantities of pollutants introduced to the Protocol area;
 - c) assess systematically the levels of pollution within their internal and territorial waters, in particular with regard to the substances that may have a potential significant impact on the Marine Environment. For the selection of the sampling locations and substances to be measured, information available, inter alia, from source inventories, discharge outfalls and marine environment characteristics shall be considered; and
 - d) evaluate the effectiveness of measures taken under this Protocol in meeting the environmental objectives.
2. Contracting States shall collaborate jointly or collectively to establish comparable monitoring programs, as well as analytical quality control programs and to promote data storage, retrieval and exchange.

ARTICLE VIII
ENVIRONMENTAL IMPACT ASSESSMENT

1. The Contracting States shall require on priority basis an assessment of the potential environmental impacts during the planning and implementation stages of selected development projects within their territories, particularly in the coastal areas, which may cause significant risks of pollution from land-based sources to the Protocol Area, in order to ensure that appropriate measures are taken to prevent or mitigate such risks.
 2. The Contracting States shall develop, with the assistance of the Organization, technical and other guidelines concerning the assessment of the potential environmental impacts of development projects referred to in paragraph 1,
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including possible trans-boundary effects. The assessment should, where appropriate, contain inter alia the following:

- a) A description of the geographical location of the activities to be carried out;
 - b) A description of the initial ecological state of the marine environment and the coastal area, which may be effected by the activities;
 - c) An indication of the nature, aims and scope of the proposed activities;
 - d) A description of the methods, installations and other means to be used;
 - e) A description of the foreseeable direct and indirect long-term and short-term effects of the activities on the Marine Environment, including fauna, flora and the ecological balance;
 - f) A statement setting out the measures proposed to reduce to the minimum the risk of pollution by carrying out the activities and, in addition, possible process and pollution abatement alternatives to such measures;
 - g) An indication of the measures to be taken for the protection of the Marine Environment from pollution during and, as appropriate, at the end of the proposed activities;
 - h) Definition of commitments to ongoing environmental management and monitoring;
 - i) Cost-benefit analysis as appropriate;
 - j) A brief summary of the assessment;
3. The implementation of the selected projects referred to in paragraph 1 should be made subject to a prior written authorization from the Competent State Authorities which takes fully into account the findings of the environmental impact assessment.
 4. The Contracting States shall co-operate with the Organization to develop procedures for the dissemination to all Contracting States of the reports on the results of such assessment with a view to enable the Contracting States which may be affected by the environmental impacts of the development projects to consult with the Contracting State concerned.

ARTICLE IX
SCIENTIFIC AND TECHNOLOGICAL CO-OPERATION

The Contracting States, in conformity with Article X of the Convention, shall cooperate in scientific and technological fields related to pollution from land-based sources, particularly research on inputs, pathways and effects of pollutants and on the development of new methods for their treatment, reduction or elimination. To this end, the Contracting States shall, in particular, endeavor to:

- a) exchange scientific and technical information;
- b) co-ordinate their research programs of common nature.

ARTICLE X
SCIENTIFIC, TECHNICAL AND OTHER ASSISTANCE

1. The Contracting States shall, directly or with the assistance of the Organization or competent Regional and International organizations, cooperate with a view to formulate and implement programs of assistance, particularly in the fields of science, education and technology, for the prevention, reduction and control of pollution from land-based sources.
2. Such technical assistance shall include, in particular, the training of scientific and technical personnel, as well as the acquisition, utilization, maintenance and production of appropriate equipment.

ARTICLE XI
WATERCOURSES SHARED BY STATES

1. If discharges from a watercourse which flows through the territories of Contracting States are likely to cause pollution of the Protocol Area, the Contracting States in question, in accordance with the provisions of this Protocol in so far as each of them is concerned, are called upon to co-operate with a view to ensuring its full application.
2. A Contracting State shall not be responsible for any pollution originating on the territory of a non-Contracting State. However, the Contracting State shall endeavor to co-operate with such State so as to make possible full application of the Protocol.

ARTICLE XII
EXCHANGE OF INFORMATION

1. The Contracting States shall inform one another directly or through the Organization of measures taken, of results achieved and, if the case arises, of difficulties encountered in the application of this Protocol. Procedures for the
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collection and submission of such information shall be determined by the Council.

2. Such information shall include *inter alia*:
 - a) Relevant statistical data in accordance with Articles VI and VII of this Protocol;
 - b) Data resulting from monitoring as provided for in Article VII of this Protocol;
 - c) Quantities of pollutants discharged or emitted from their territories;
 - d) Measures taken in accordance with Articles IV, V and VI of this Protocol.

ARTICLE XIII RESPONSIBILITY AND LIABILITY FOR DAMAGE

1. Contracting States shall ensure that recourse is available in accordance with their legal systems for prompt and adequate compensation or other relief in respect of damage caused by pollution of the Marine Environment by natural or juridical persons under their jurisdiction.
2. Contracting States shall formulate and adopt appropriate procedures for the determination of liability for damage resulting from pollution from land-based sources.

ARTICLE XIV INSTITUTIONAL ARRANGEMENTS

The Council, in accordance with Article XVII of the Convention, shall be responsible for keeping under review the implementation of this Protocol. To this end, the Council shall, *inter alia*:

- a) consider the efficacy of the measures adopted and the advisability of adopting any other measures, in particular in the form of annexes;
- b) revise and amend any annex to this Protocol, as appropriate;
- c) formulate, adopt and review programs and measures in accordance with Articles IV, V, VI, VII, IX and X of this Protocol;
- d) adopt Regional guidelines, standards or criteria in accordance with Articles IV, V and VI of this Protocol;
- e) formulate procedures for exchange of information in accordance with Articles VIII and XII of this Protocol;
- f) consider information submitted by the Contracting States under Articles VIII and XII of this Protocol;

- g) discharge such other functions as appropriate for the application of this Protocol; and
- h) establish any such institutional mechanism as deemed necessary for the achievement of the objectives of this Protocol.

**ARTICLE XV
GENERAL PROVISIONS**

1. The provisions of the Convention relating to any Protocol shall apply to this Protocol.
2. Procedures for amendments to Protocols and their Annexes adopted in accordance with Articles XX and XXI of the Convention shall apply to this Protocol.
3. The Rules of Procedures and Financial rules adopted pursuant to Article XXII of the Convention, and amendments thereto, shall apply to this Protocol.
4. The Annexes form an integral part of this Protocol unless expressly provided otherwise thereto.

**ARTICLE XVI
FINAL PROVISIONS**

1. This Protocol shall be open for signature in the State of Kuwait from 21 February to 21 May 1990 by any State which is party to the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from pollution.
2. This Protocol shall be subject to ratification, acceptance, approval or accession by the States parties to the Convention. Instruments of ratification, acceptance, approval or accession shall be deposited with the Government of Kuwait which shall assume the functions of the Depository.
3. This Protocol shall enter into force on the ninetieth day following the date of deposit of at least five instruments of ratification, acceptance or approval of, or accession to this Protocol by the States as referred to in paragraph 1 of this Article.

In WITNESS WHEREOF the undersigned Plenipotentiaries, being duly authorized by their respective Governments, have signed this Protocol.

DONE AT KUWAIT this twenty-first day of February, in the year one thousand nine hundred ninety in the Arabic, English and Persian languages, the texts being equally authentic.

Annex 1 to the protocol

POLLUTION ABATEMENT THROUGH SOURCE CONTROL

With regard to the issue of pollution abatement through source control referred to in Article IV of this Protocol, consideration should be given to the control and progressive replacement of products, installations and industrial or other processes causing significant pollution to the Marine Environment. In this regard, particular attention will be given, but not limited, to the following factors:

- a) Curtailment and/or regulation of import, transportation, manufacturing or processing of certain harmful substances.
- b) Change of raw materials.
- c) Change of manufacturing processes.
- d) Good operating and housekeeping practices.
- e) Segregation of waste streams and minimization of pollutant dilution prior to treatment.
- f) Recovery, re-use and recycling.

The programs, measures and the timetables required for the implementation of source control will be developed and priorities allocated on the basis of the results of on-going assessment studies.

Problem areas of Regional interest, where cost effective measures can be implemented, will receive attention for the purpose of establishing general management schemes. Such areas are, for example, the collection, treatment, and proper disposal of spent lubricating oils, blood and paunch from slaughterhouses, the control of fuel combustion processes and the implementation of source control in selected processes within large industries.

Annex 2 to the protocol

PROMOTION OF JOINT AND/OR COMBINED EFFLUENT TREATMENT

Without undue prejudice to the multifaceted constraints that often govern the selection of the location of new industries, a program will be undertaken, as referred to in Article VI of this Protocol, to promote:

- a) agglomeration of industries in a way that enhances the possibility of joint effluent pretreatment and/or treatment, as the need may be;
- b) location within the limits of city sewer systems of certain types of industry so as to enhance combined treatment of industrial and domestic wastes.

Promotion of joint and/or combined effluent treatment, if properly planned, could result in greatly reduced treatment, monitoring and enforcement costs as well as in increased treatment reliabilities. To this end, Regional guidelines and criteria will be developed dealing with topics of common interest, such as:

- the compatibility of effluent from different sources;
- pretreatment requirements prior to discharge into domestic and/or industrial sewer systems;
- cost sharing for the construction and operation of treatment plants.

Such guidelines and criteria will assist Contracting States in developing their own specific programs and measures. While initial plans may deal with the location problem of new industries, the end objective will be the progressive attraction of existing selected small industries as the infrastructure and facilities are developed in the designated areas.

Annex 3 to the protocol

GUIDELINES, REGULATIONS AND PERMITS FOR THE RELEASE OF WASTES

1. With a view to guidelines, standards or criteria, as well as to regulations, programs, measures, and discharge permits for release of wastes referred to in Article VI of this Protocol, particular attention will be given, *inter alia*, to the following factors:
 - a) Regional regulations for the waste discharge and/or degree of treatment should be specific for each kind of source and, if necessary, may be different between existing and new sources. Their development should be based on treatment technology, cost and nature of pollutants considerations, as well as on an overview of the state of environment in the Protocol Area.
 - b) Regional guidelines and, as appropriate, standards or criteria should be developed for the quality of sea water used for specific purposes.
 - c) For areas where the water quality standards for the intended use cannot be achieved through the implementation of the above regional regulations, stricter local regulations for the waste discharge and/or degree of treatment should be developed. Such local regulations will apply to the specific sources in the areas under consideration.
 - d) Regional regulations along with the programs, measures and the timetables required for the implementation should be developed on a priority basis, *inter alia*, for the following types of wastes:
 - i) Ballast water, slops, bilges and other oily water discharges generated by land-based reception facilities and ports through loading and repair operations.
 - ii) Brine water and mud discharges from oil and gas drilling and extraction activities from land-based sources.
 - iii) Oily and toxic sludges from crude oil and refined products storage facilities.
 - iv) Effluents and emissions from petroleum refineries.
 - v) Effluents and emissions from petrochemical and fertilizer plants.

- vi) Toxic effluents and emissions from industries such as chlor-alkali, primary aluminum production, pesticides, insecticides, and lead recovery plants.
 - vii) Emissions from natural gas flaring and desulfurization plants.
 - viii) Dust emissions from major industrial sources, such as cement, lime, asphalt and concrete plants.
 - ix) Effluent and emissions from power and desalination plants.
 - x) Wastes generated from coastal development activities which may have a significant impact on the Marine Environment.
 - xi) Sewage and solid waste.
- e) As the Diagram 1 attached to this Annex illustrates, pollution abatement is an iterative process. Pollution abatement action will start from high priority measures, which will be selected to be pragmatic cost-effective, while addressing the most critical environmental problems as perceived today. The monitoring program as specified in Article VII of this Protocol, will be providing the necessary feedback for the required corrective action by yielding the database for accessing the effectiveness of implemented programs, the current state of the environment and its trends. Corrective action, whenever required, will be taken through periodic updates of the regulations, programs and measures and review of the conditions in discharge permits, in accordance with the provisions of Articles IV and VI of this Protocol.

2. Provisions for establishing criteria governing the issue of permits for the discharging of waste matter in the Marine Environment, should also take into consideration inter alia the following:

- a) Characteristics and Composition of Waste
 - i) Type and size of waste source, e.g. industrial process.
 - ii) Type of waste (origin, average composition).
 - iii) Form of waste (solid, liquid, sludge, slurry).
 - iv) Total amount (volume discharged, e.g. per year).
 - v) Discharge pattern (continuous, intermittent, seasonally variable, etc.).
 - vi) Concentrations with respect to major constituents.
-

- vii) Properties: physical, e.g. solubility and density chemical and biochemical, e.g. oxygen demand, nutrients, and biological, e.g. presence of viruses, bacteria, yeast, parasites.
 - viii) Toxicity
 - ix) Persistence: physical, chemical and biological.
 - x) Accumulation and bio-transformation in biochemical materials or sediments.
 - xi) Susceptibility to physical, chemical and biochemical changes and interaction in the aquatic environment with other dissolved organic and inorganic materials.
 - xii) Probability of producing taints or other changes reducing marketability of resources, e.g. fish, shellfish, etc.
- b) Characteristics of Discharge Site and Receiving Marine Environment.
- i) Hydrographic, meteorological, geological, biological and topographical characteristics of the discharge site.
 - ii) Location and type of the discharge (outfall, canal, outlet, etc.) and its relation of other areas, e.g. amenity areas, spawning, nursery and fishing areas, shellfish grounds and exploitable resources.
 - iii) Rate of disposal per specific period, e.g. quantity per day, per week and per month.
 - iv) Initial dilution achieved at the point of discharge into the receiving marine environment.
 - v) Methods of packaging and containment, if any.
 - vi) Dispersion characteristics such as effects of current, tides and wind on horizontal transport and vertical mixing.
 - vii) Water characteristics, e.g. temperature, pH, salinity, stratification, oxygen indices of pollution - dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD) - nitrogen present in organic and mineral form including ammonia, suspended matter, other nutrients and productivity.

viii) Existence and effects of other discharges which have been made in the discharge site, e.g. heavy metal background levels and organic carbon content.

c) Availability of Waste Technologies

The methods of waste reduction and discharge for industrial effluent as well as domestic sewage should be selected taking into account the availability and feasibility of:

- i) Alternative treatment processes;
- ii) Re-use or elimination methods;
- iii) On-land disposal alternative; and
- iv) Appropriate low-waste technologies.

d) General Considerations and Conditions

- i) Possible effects on amenities, e.g. presence of floating or stranded materials, turbidity, objectionable odour, discoloration and foaming.
 - ii) Effects on human health through pollution impact on : Edible marine organisms, bathing waters, aesthetics;, etc.
 - iii) Effects on marine ecosystems, in particular living resources, endangered species and critical habitats.
 - iv) Possible effects on other uses of the sea, e.g. impairment of water quality for industrial use, underwater corrosion of structure, interference with ship operations from floating materials, interference with fishing or navigation through deposit of waste or solid objects on the sea floor and protection of areas of special importance for scientific or conservations purposes.
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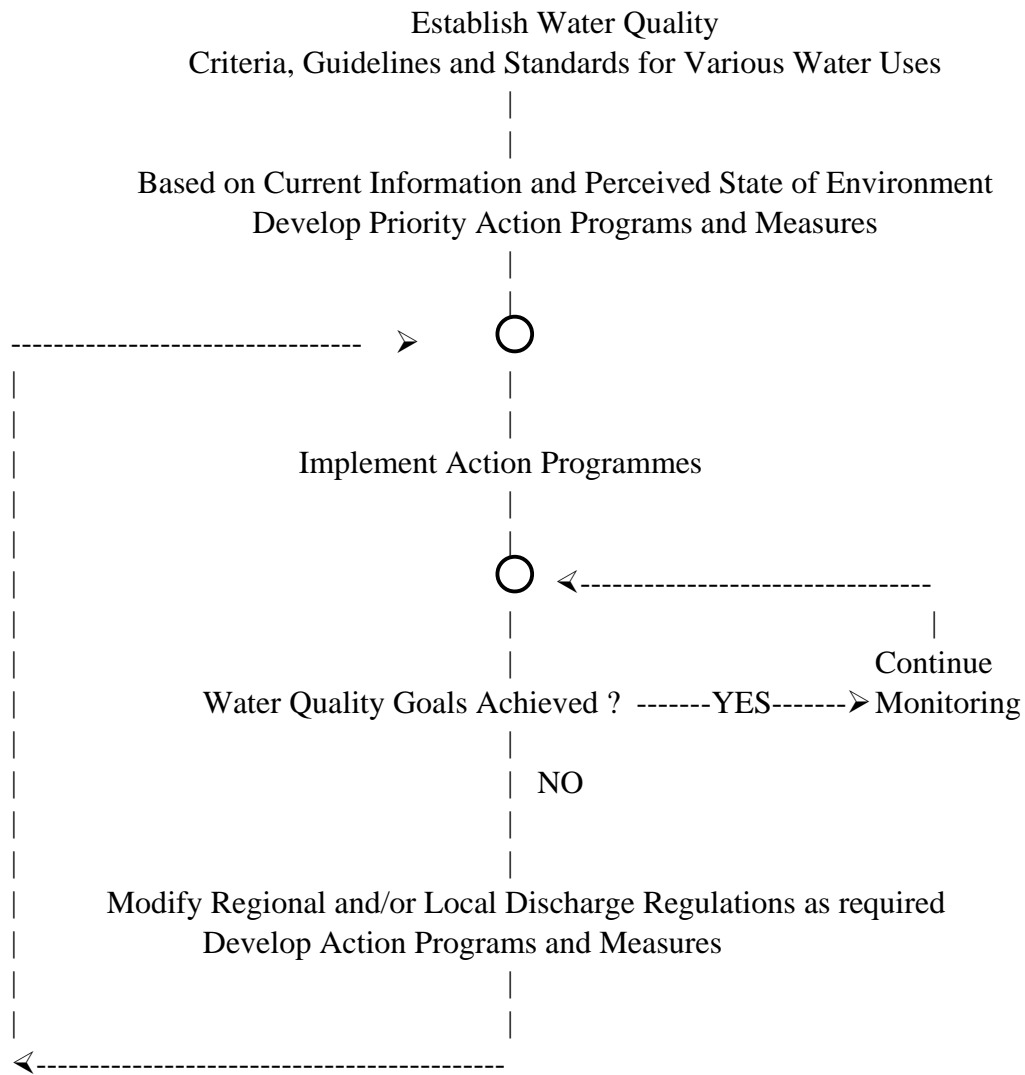


Diagram 1: Environmental Management Scheme

10.2 APPENDIX II

Characteristics of industrial effluents

Industrial activity	Waste characteristics	Parameters of concern
Canned/preserved seafood	Protein, fats, organics, odor	BOD, COD, TSS, oil & grease
Canned/preserved fruits & vegetables	SS, colloidal/dissolved organics	BOD
Diary products	Dissolved organics, fats, lactose	BOD, COD, TSS, TDS, pH
Brewery	Dissolved organic solids, fermented starches	BOD
Meat and poultry products	Dissolved and suspended organics, proteins, fats	BOD, COD, TDS, oil & grease
Animal feedlots	Organic suspended solids	BOD, COD, color, oil & grease
Sugar beet	Dissolved/suspended organics	BOD, COD, TSS, TDS
Pharmaceutical products	Suspended & dissolved organics incl. vitamins	BOD, TSS, TDS
Coffee production	Organics	BOD, TSS
Grain mills	Organics, solids	BOD, COD, TSS, pH, P
Soft drinks	Suspended solids, organics	BOD, COD, TSS, pH
Textiles	Highly alkaline, colored, high temperature	BOD, COD, TSS, pH, Cr, Zn, toxic organics
Tanneries	High total solids, salt, lime, chromium, sulfides	BOD, COD, TSS, Cr, sulfides
Pulp & paper	Organics, high colloidal suspended and dissolved solids, color	BOD, TSS, pH, color
Photographic products	Alkaline, organic/inorganic reducing agents	Metals, CN^-
Steel	Acids, phenols, oils, fine suspended matter	BOD, CN^- , Pb, Zn, sulfides
Non-ferrous metals	Metals, acids, slag, lime sludge	TDS, TSS, pH, F, Cu, Pb, Zn, Cd, As, Se
Metal plated products	Acids, metals, toxic materials	TSS, pH, CN^- , P, F, Cr, Cu, Pb, Zn, Cd, Fe, Ni
Oil refineries	Dissolved salts, high organics, odor, sulfur compounds	BOD, NH_3 , Zn, phenols, oil & grease
Rubber production	High suspended, chlorides	BOD, COD, TSS, Pb, Zn
Glass	Color, suspended solids	BOD, COD, TSS, pH, phenols

Industrial activity	Waste characteristics	Parameters of concern
Glue manufacture	Mineral acids, organics	BOD, COD, pH, Cr, phenols
Candle manufacture	Fatty acids	BOD, COD, TDS
Paints & inks	Dissolved organics, metals, oils	BOD, COD, TSS, TDS, pH, Cr, Cu, Pb, Zn, Cd, Fe
Fertilizers	Clays, slimes, acid wastes	TSS, pH, P, NH ₃ , F, K
Explosives	TNT, acids, metals, oils	COD, NH ₃
Pesticides	High organic matter, toxics, acids	BOD, COD, toxic organics
Plastics & resins	Acids, caustic, nitrogenous compounds, phenols, formaldehyde	BOD, COD, TSS, TDS, pH, F, Cr, phenols
Steam power	High volumes, high temperature, inorganic & dissolved solids	TSS, pH, Cr, Cu, Zn, Fe, phenols
Coal processing	Suspended solids, acid, sulfuric acid	COD, TSS, pH, SO ₄ ²⁻
Soap & detergents	Organic & saponified soaps	BOD, COD, TSS, TDS, oil & grease



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