AN INTEGRATED APPROACH TO WASTEWATER MANAGEMENT

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ABSTRACT

Wastewater management focused, for many years, on the treatment of wastewater to protect the environment and safeguard the public health. An integrated approach to wastewater management is more extensive and includes the control of generation, collection and transport, treatment, disposal and reuse of wastewater in a manner that is in accord with the best principles of public health, economics, technology, conservation, aesthetics, and other environmental considerations. Regarding the seriousness of the environmental problems society now faces, the role of public policy is increasing to establish goals for wastewater management. Implementation of these goals is achieved by the adoption of standards and the development of criteria, regulations, and guidelines that constitute an integral part of the wastewater management.

This paper outlines a systemic approach to be followed in wastewater management. The paper also examines the interrelationships between the functional elements in a wastewater management system and presents current trends in the generation, collection, treatment, disposal, and reuse of wastewater in the Arab region in order to derive a simplified management framework. The effluent quality to be attained by each system is defined by standards issued by the responsible regulatory agency. The fundamental rationale is based on correcting deficiencies in water quality to meet the criteria for water reuse or marine disposal.

KEYWORDS

Environmental management, marine disposal, treatment technologies, wastewater collection, water quality standards, water reuse.

INTRODUCTION

Every community generates both liquid and solid wastes. The liquid waste, i.e. wastewater, is essentially the water supply of the community after it has been fouled by a variety of uses such as residential, institutional, commercial and industrial. Water pollution occurs when the discharge of wastewater into water bodies impairs water quality or disturbs the natural ecological balance in the receiving environment, that is often the marine environment. The wastewater contaminants which cause problems are numerous and include organic matter, solids, pathogens, nutrients, toxic substances, color, foam, heat, and radioactive materials. Many treatment processes are available each of which can accomplish certain types of quality changes.

For most developing nations, where environmental problems are often critical and available resources scarce, difficulties in formulating sound environmental management programs are pronounced. For instance, wastewater management approaches based on the best available control technology implemented in developed nations tend to be too expensive and are often not suitable for developing nations. The systems analysis approach for wastewater management is believed to be better suited for developing nations as it offers a practical procedure for formulating cost-effective strategies, targeted at selected critical problems, as well as detailed action programs which facilitate strategy implementation (Economopoulos, 1993). This approach can contribute to better health and environmental quality protection, to conservation of valuable resources, and to unobstructed development in a rational and sustainable manner (Hamoda, 1995). It will also permit the standardization of the critical initial stages of the planning process.

Wastewater management is multidimensional. It embraces planning, design, construction, operation and maintenance of wastewater collection, treatment, disposal and reuse systems. The functional elements for municipal wastewater management systems are outlined in Table 1 (Metcalf & Eddy, 1991). The interrelationship of these functional elements is important for proper management.

Municipal wastewater systems provide the basis for increasing urbanization and industrial growth in many localities. New facilities are constructed but numerous facilities constructed in the past are reaching their design flows, and the question of how to rehabilitate them is becoming important. The maturity of wastewater infrastructure suggests that the exercise of good management practices be the basis for correcting deficiencies and making improvements. The development and management of wastewater treatment and reuse have been influenced by many technological, social, political, organizational, and economic factors. Such factors have to be considered for the ensuing management strategy.

The following sections will discuss the wastewater management aspects and attempt to derive a management framework for the Arab countries. The formulation of optimal control strategies requires the analysis of existing problems and the identification of the most critical ones, the setting of definite objectives and the development of effective action programs to have them fulfilled. These steps will be described in brief for the case of wastewater management.

Table 1. Major elements of wastewater management systems and associated tasks (Metcalf & Eddy, 1991)

Element	Engineering task
Wastewater generation	Estimation of the quantities of wastewater, evaluation of techniques for the reduction of wastewater, and determination of wastewater characteristics
Source control (pretreatment)	Design of systems to provide partial treatment of wastewater before it is discharged to collection systems (principally involves industrial dischargers)
Collection system	Design of sewers used to remove wastewater from the various sources of wastewater generation
Transmission and pumping	Design of large sewers (often called trunk and interceptor sewers), pumping stations, and force mains for transporting wastewater to treatment facilities or to other locations for processing
Treatment (wastewater and sludge)	Selection, analysis, and design of treatment operation and processes to meet specified treatment objectives related to the removal of wastewater contaminants of concern
Disposal and reuse (wastewater and sludge)	Design of facilities used for the disposal and reuse of treated effluent in the aquatic and land environment, and the disposal and reuse of sludge
Small systems	Design of facilities for the collection, treatment, and disposal and reuse of wastewater from individual residences and small communities

WASTEWATER MANAGEMENT ASPECTS

Identification of critical issues of wastewater management is of great practical importance in setting clear control priorities and overall strategy directives. In the Arab region, there is a rather unique combination of conditions that should be considered in the formulation of strategies and determination of cost-effectiveness of wastewater management approaches. Major issues are:

1. Growing population (about 4% increase per year) and industrialization have considerably increased wastewater quantities generated.

2. Lack of fresh water makes wastewater a valuable resource. Therefore, wastewater collected from communities must be ultimately returned to the land.

3. Abundant desert land is often in close proximity to cities.

4. The climate is warm and arid. Health and environmental impacts of wastewater disposal are becoming a matter of greater concern to regulatory agencies and the public.

5. Major industries are usually placed in industrial ones and, as a result, municipal wastewater is often free from toxic substances.

6. Construction and operation of wastewater treatment plants is becoming very costly as more effective treatment processes are adopted.

7. Lack of trained personnel for the operation and maintenance of wastewater facilities.

8. Traditional funding sources for wastewater projects come from government which sets priorities to cities and towns for short-term and long-term financing.

9. Institutional and administrative constraints that limit what can be done and impair enforcement of water quality standards.

COMPONENTS OF WASTEWATER MANAGEMENT SYSTEMS

A simplified diagram of the basic elements of municipal wastewater management systems is shown in Fig. 1. These functional elements are interrelated. They include (1) the individual sources for wastewater generation, (2) collection and transmission facilities, (3) treatment facilities, (4) disposal and reuse facilities, and (5) the ultimate receiver of wastewater. Two important factors that must be addressed in the implementation of a wastewater management system are quantity and quality as illustrated in Table 2.

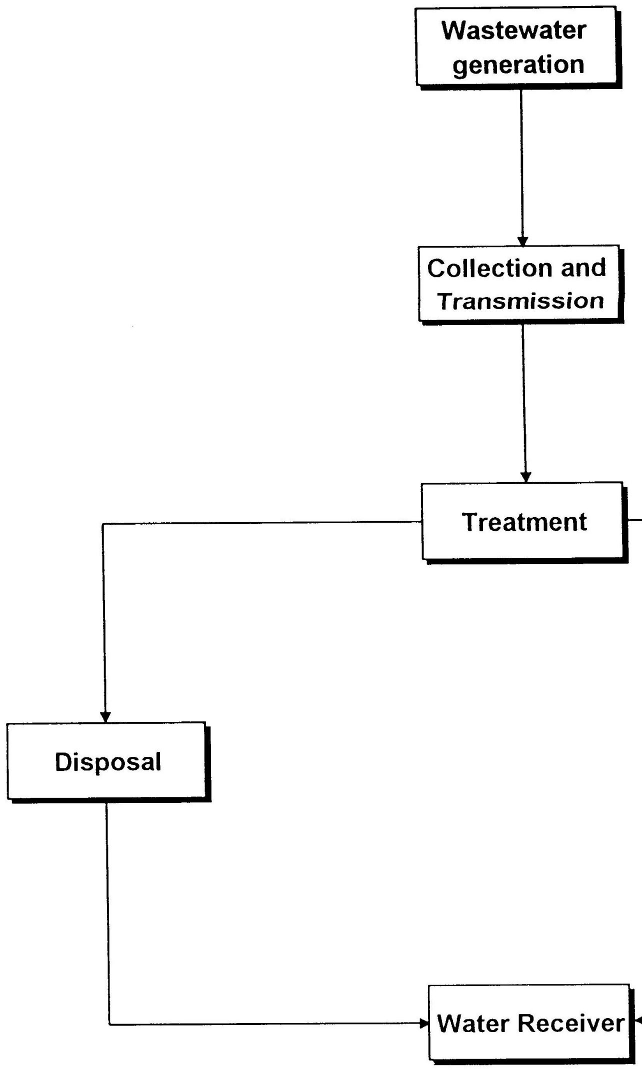

Fig. 1. Simplified diagram of the functional elements in a wastewater management system

Table 2. The functional elements of municipal wastewater management systems

Functional element	Principal concerns in facilities design (primary/secondary)	Description
Generation	Quantity/quality	Sources of wastewater in a community, such as residences, commercial establishments, and industries
Collection	Quantity/quality	Facilities for collection of wastewater from individual sources in a community
Transmission	Quantity/quality	Facilities to pump and transport collected wastewater to processing and treatment sites
Treatment	Quality/quantity	Facilities for treatment of wastewater
Reuse/disposal	Quality/quantity	Facilities for reuse and disposal of treated effluent and residual solids resulting from treatment
Receiver	Quality/quantity	Lakes, rivers, seas, oceans, and land

The formulation of rational strategies for wastewater management is influenced by two major fundamental elements, namely the wastewater collection system and receivers of wastewater. The most common receivers are lakes, rivers, coastal waters, and land. At the very end of the management system. Selection of the wastewater receiver(s) is a key issue that has to be addressed in the early stages of the strategy formulation procedure, as it defines quite rigidly the ensuing strategy framework as well as the severity of the treatment efficiency requirements.

SYSTEM ANALYSIS

Planners can proceed into the formulation of strategies once the basic elements of the management system are defined and the fundamental issues of wastewater collection system and receivers are settled. This can be illustrated for each element (Fig. 1) as follows:

Wastewater Generation

Controls at the source represent in many cases an approach, not only environmentally responsible, but also economically sensible. Moreover, the relevant solutions tend to be by far the simplest and the fastest to implement. It is important to minimize the quantities of wastewater generated by reducing water consumption rates. Moreover, the quality of wastewater could be also controlled. In domestic wastewaters, it is possible to reduce or eliminate certain harmful substances by replacing the consumer products in which they are contained by other environmentally friendlier ones. The best known relevant measure is the replacement of the phosphatic detergents by non phosphatic ones. Dumping of strong wastes into the municipal wastewater collection system should be prohibited.

Collection and Transmission of Wastewater

The design of collection systems must be also reviewed in the early strategy formulation stages along with the selection of the final receiver(s) as the type and the design of the collection system affects profoundly the control possibilities and the ensuing management strategy. Issues such as the possible lack of central (main) collectors, bad design of the system with frequent overflows, or combined collection of wastewaters and rain run-off, need to be carefully reviewed and resolved, prior to proceeding in the formulation of treatment strategies. Moreover, expansion of the sewerage system might have to be considered so as to address the choice of the final receiver and the possible combined treatment from neighbouring industries and/or communities. On the other hand, transmission of wastewater in open channels and/or in pressure conduits as well as pumping smut be considered along with the selection of the final receiver(s).

Wastewater Treatment

Treatment technologies offer effective ways to reduce the strength of wastes making them suitable for disposal or reuse. The applicable technologies and the combination of the processes depend very much on the nature of the wastes and on the desirable system efficiency in relation to the critical pollutants.

The fundamental rationale in wastewater treatment, as in municipal water treatment, is based on correcting deficiencies in quality. The rational approach in selecting treatment systems begins with a critical comparison of raw wastewater quality and required effluent characteristics. The effluent quality that must be attained is defined by standards issued by the responsible regulatory agency. When a comparison of standards and wastewater characteristics indicates that improvements in effluent quality are necessary before discharge, treatment is indicated.

Many treatment processes are available, each of which can accomplish certain specific types of quality changes. Some examples of processes used in practice to remove potential pollutants from municipal wastewaters are listed in Table 3, along with information about the extent to which they are employed currently. The selection of the specific sequence of processes to be used in a given plant depends on the matrix of pollutants that must be removed, efficiencies that must be attained, and capital and operating costs for the entire treatment system (Linsley et al., 1992).

Several treatment processes and systems commonly used in municipal practices are described in subsequent sections of this chapter. In those discussion, wastewater treatment is divided into a few broad categories, each of which is directed toward attaining certain goals: (1) preliminary treatment, (2) primary treatment, (3) secondary or biological treatment, (4) advanced treatment, and (5) adjunct processes that are necessary to complete the plant functionally.

Table 3. Treatment processes available for municipal wastewaters

Constituent to Be Removed	Process	Status of Use in Practice		
		Frequently	**Sometimes**	**Few or None**
Large solids	Bar screens	X		
	Comminutors	X		
Suspended solids	Fine screens		X	
	Settling	X		
	Flotation		X	
	Coagulation		X	
	Sand filtration		X	
Biodegradable organics (BOD)	Storage ponds			X
	Aerated lagoons		X	
	Oxidation ponds	X		
	Activated sludge	X		
	Trickling filters	X		
	Activated carbon			X
Other organics	Activated carbon		X	
Nitrogenous oxygen demand (NOD)	Nitrification		X	
	Stripping			X
	Ion exchange			X
Nitrogen removal	Nitrification/de nitrification			X
	Stripping			X
	Ion exchange			X
Oils	Gravity dotation		X	
	Air flotation		X	
Inorganics	Reverse osmosis			X
	Ion exchange			X
	Precipitation		X	
	Fleet rodialysis			X
	Distillation			X
	Freezing			X
Sludge digestion	Anaerobic	X		
	Aerobic		X	
Sludge dewatering	Flotation		X	
	Filtration	X		
	Centrifugation	X		
	Gravity thickening	X		
	Incineration		X	

The combination of wastewater management aspects in the Arab region discussed previously makes the use of the natural treatment systems, such as waste stabilization ponds, ideal in many cases. Indeed:

1. The high ambient temperatures ensure year-round high microbial removal efficiencies, with relatively low land requirements.
2. The treated effluents can be suitable for irrigating crops, even these that are eaten raw. This conserves valuable fresh water resources and may provide additional agricultural production possibilities.
3. The near-by deserts or shallow semi-saline lakes provide ample space for pond construction, as well as land for agricultural development.
4. The usual lack of toxic substances from municipal wastes makes them suitable candidates for land disposal.

Natural treatment systems have a very low capital cost, assuming that the cost of desert land is low. Their cost of operation and their operator skill requirements are the lowest while their treatment reliability is the highest. Most of the construction can be based on local resources with few imports. In addition, the treated effluents can be suitable for food irrigation and this can be achieved only through expensive tertiary treatment processes if other biological treatment methods are selected.

Under the above conditions extensive utilization of natural treatment processes along with land disposal of the treated effluents can maximize the impact of the available resources or result in very significant savings, and make available valuable irrigation water while eliminating coastal pollution.

Wastewater treatment technology aims to reduce the strength of wastes making them suitable for reuse (e.g. land application) or for safe disposal into the receivers. The applicable technologies and the combination of processes depend very much on the nature of the wastes and their discharge mode, as well as on the desirable system efficiency in relation to critical pollutants.

Treatment efficiency requirements constitute a key parameter for the selection of the plant configuration which best serves the needs of a particular application. This, however, is not the only parameter: other important ones also need to be considered. Among these the cost of construction and operation, and the operational reliability, both of which depend on local conditions, are perhaps the most important, as they inevitably interfere with the choice of treatment processes in every new installation.

Municipal, predominantly domestic, wastes represent the most common type of effluent, and for this reason, their treatment is fairy well standardized and of particular importance in water pollution management. Table 4 presents some qualitative information about the expected performance efficiencies of certain commonly used treatment processes. Furthermore, Tables 5 and 6 provide qualitative guidance regarding the relevant cost and performance reliability of secondary (biological) treatment processes.

The information presented in these tables covers the predominant parameters that affect the configuration of every treatment plant. Naturally, the eventual configuration is normally the product of a detailed analysis. However, a good idea can be obtained at the strategy formulation stages through consideration of the listed information along with the local conditions and nature of problems.

Table 4. Degree of treatment achieved by various unit operations and processes used in primary and secondary treatment (Metcalf & Eddy, 1991)

	Constituent removal efficiency, percent					
Treatment units	**BOD**	**COD**	**SS**	**P[b]**	**Org-N[c]**	**NH_3-N**
Bar racks	nil	nil	nil	nil	nil	nil
Grit chambers	0-5[d]	0-5[d]	0-10[d]	nil	nil	nil
Primary sedimentation	30-40	30-40	50-65	10-20	10-20	0
Activated sludge (conventional)	80-95	80-85	80-90	10-25	15-50	8-15
Trickling filters						
High rate, rock media	65-80	60-80	60-85	8-12	15-50	8-15
Super rate, plastic media	65-85	65-85	65-85	8-12	15-50	8-15
Rotating biological contactors (RBCs)	80-85	80-85	80-85	10-25	15-50	8-15
Chlorination	nil	nil	nil	nil	nil	nil

[b] P = Total phosphorus.
[c] Org-N = Organic nitrogen.
[d] The higher numbers apply if grit washers are not used.

Table 5. Comparison of cost parameters for biological treatment processes (Economopoulos, 1993)

Land Requirements:

High

Waste Stabilization Ponds
- Area, m^2/capita: 2-4 (warm) & 4-12 (temperate)

Facultative Aerated Lagoons
- Area, m^2/capita: 0.15-0.45 (warm) & 0.45-1.00 (temperate)

Extended Aeration Systems
- Area-; m^2/capita: 0.25-0.35 (warm) & 0.35-0.65 (temperate)

Conventional Activated Sludge
- Area. m^2/capita: 0.16-0.20 (warm) & 0.20-0.40 (temperate)

Low

Trickl ing Filters
- Area. m^2/capita: 0.16-0.20 (warm) & 0.20-0.40 (temperate)

Cost of Construction (Excluding Land Cost):

Extended Aeration Systems

High

Equipment:	Aerators, recycle pumps, sludge scrapers
Economy of scale*:	Considerable

Conventional Activated Sludge

Equipment:	Aerators, recycle pumps, scrapers, thickeners, digesters, driers
Economy of scale*:	Small

Trickling Filters

Equipment:	Effluent distributors
Economy of scale*:	Small

Facultative Aerated Lagoons

Equipment:	Aerators only
Economy of scale*:	Very small

Waste Stabilization Ponds

Low

Equipment:	Nil
Economy of scale*:	Very small

Operating Cost:

Conventional Activated Sludge

High

Operation.	Skilled operators / tight control
Sludge Handling:	Drying beds or Mechanical dewatering
Power Requirements:	12-17 kWh/person/year

Extended Aeration Systems

Operation:	Skilled operators
Sludge Handling:	Digestions-Drying beds/Filters
Power Requirements:	13-20 kWh/person/year

Trickling Filters

Operation:	Relatively simple
Sludge Handling:	Digestions-Drying beds/Filters
Power Requirement:	Low

Facultative Aerated Lagoons

Operation:	Very simple
Sludge Handling:	Manual desludging every 5-10 years
Power Requirements:	12-15 kWh/person/year

Waste Stabilization Ponds

Operation:	Simplest (Part time operator for smaller units)
Sludge Handling:	Manual desludging every 5-10 years
Power Requirements:	0 kWh/person/year

Low

* Sensitivity of Unit Cost (construction cost per capita) to the Size of Population Served

Disposal / Reuse of Wastewaters

Disposal of wastewaters is accomplished by discharging the waste effluents into coastal wasters, lakes and rivers. This represents an indirect reuse of the water since the water bodies into which the wastewater is disposed off are the common sources for water supply. On the other hand, disposal of wastewater on land, as an alternative to disposal into water bodies constitutes a direct means of water reuse.

Disposal into Coastal Waters:

The marine environment has a significant capacity to assimilate the waste loads discharged. The sea constitutes thus the receiver of choice compared to surface waters. Disposal at sea however, is not without pollution problems if wastes are not properly treated and if the outfall system is not properly designed to provide the necessary dilution.

Table 6. Comparison of the operating reliability of biological treatment processes (Economopoulos, 1993)

Adaptation to Organic and Toxic Shock Loads:	
High	Waste Stabilization Ponds
↓	Facultative Aerated Lagoons
	Trickling Filters
	Extended Aeration Systems
Low	Conventional Activated Sludge
Suitability for Intermittent Operation:	
High	Waste Stabilization Ponds
↓	Facultative Aerated Lagoons
	Trickling Filters, Biodiscs
	Extended Aeration Systems
Low	Conventional activated Sludge
Independence from Operators' Training:	
High	Waste Stabilization Ponds
↓	Facultative Aerated Lagoons
	Trickling Filters, Biodiscs
	Extended Aeration Systems
Low	Conventional Activated Sludge

Disposal into Lakes:

Lakes are the natural collectors of water runoff from large drainage areas, and often of the direct or indirect discharges from industrial and domestic sources. Lakes are sensitive receivers and eutrophication, i.e. enrichment of nutrients causing symptomatic changes such as production of algae and deterioration of water quality, is their most common and serious problem.

Disposal into Rivers:

Rivers, like lakes, are the natural collectors of rain runoff from large drainage areas and often of the direct or indirect discharges from domestic sources. However, rivers are less sensitive receivers compared to lakes. Meanwhile, rivers have been the principal suppliers of fresh water to cities, agriculture, and industry, as well as receivers for their discharges. Thus, while the maintenance of satisfactory water quality is a necessity, river pollution has often been a serious problem.

Land Application:

Land disposal could be an attractive option in cases where the water is relatively scarce, irrigable land is close to the treatment plant, and the wastewater is free from toxic substances.

The land disposal of wastewaters results in water conservation through reuse, thus saving valuable fresh water for other uses, reduces or eliminates the pollution of surface waters, especially during the low-flow summer period, and can increase the crop yield, due to the presence, not only of nitrogen and phosphorus nutrients, but also of other fertilizing substances and "growth factors". Along with the above advantages, potential land pollution problems and health hazards exist, and should be carefully considered (ESCWA, 1985).

Water reuse is not limited to land irrigation. Other reuse practices include groundwater recharge, fire fighting, cooling, industrial operations, recreational activities and water supply blending.

Disposal of sludge (biosolids) generated at treatment plants is accomplished through dumping in oceans, spreading on land as a fertilizer, or burying of ashes resulting from sludge incineration. The sludge is treated by dewatering and biological stabilization prior to disposal.

Water Receivers

Critical water quality objectives can be set by considering the nature of the wastewater receivers and their particular sensitivities. Indeed, these sensitivities are so dominant, that strategies formulated and control systems designed to address the relevant critical problems tend to satisfy all other receiver-quality objectives. An outline of critical objectives for the most common receivers are summarized below:

For coastal (marine) waters, microbial pollution is the critical problem when municipal waste waters are involved. Eutrophication, caused by high BOD loadings, may also be a problem when wastes are discharged into enclosed bays or harbors. Moreover, with the possible exception of the sea in cases of strong currents, the aquatic life is affected by the discharge of suspended solids.

For rivers, the critical pollution problem is the oxygen deficiency caused by the discharge of organic loads. Microbial pollution can also be a critical problem if municipal wastewater discharges are involved.

For lakes, the critical pollution problem is eutrophication and the pollutant that usually controls this problem is phosphorus. Moreover, the aquatic life is affected by the discharge of suspended solids.

For land disposal, pathogen transmission is a critical problem, provided that sufficient land area is available so as to meet the critical hydraulic and organic loading restrictions.

An additional objective, common to all receivers, is the effective control of toxic substances. Especially stringent are the requirements for the toxic persistent chemicals contained in the "black list" of the United Nations Environment Program (UNEP, 1985) the discharges of which should be eventually eliminated. Land exhibits the highest sensitivity among receivers due to the accumulation of toxics, and disposal of wastes containing toxics, in other than trace amounts, is not recommended unless carefully studied.

Priorities among alternative receivers typically rank as follows: Open coast, enclosed bay or harbor, river, lake (Economopoulos, 1993). The disposal on land may have a high priority depending on the suitability of the wastes (lack of toxic and persistent substances, relatively low dissolved and suspended solids, presence of phosphorus and nitrogen nutrients), on the nature of the irrigated soil, on the types of crops raised, and especially on the climatological conditions (in arid or semi arid regions the reused wastewater may constitute a valuable asset). Through this, valuable fresh water can be saved for other uses, pollution of surface waters could be eliminated, especially during the low-flow summer period, and increased crop yields obtained due to the presence of nutrients and "growth factors".

FORMULATION OF STRATEGIES

The formulation of rational strategies can be pursued once the fundamental issues of the municipal wastewater collection system and receivers are settled and integrated with functional elements of the wastewater management program. This can be achieved through computation of effluent loads, analysis of the impact of such loads on the receivers and assessment of the treatment efficiency requirements. One has to carefully consider the particular sensitivities associated with each type of waste receiver. These impose definite priorities, distinctly characteristic of the receiver type, in the control of particular pollutants and define, to a large extent, the severity of the wastewater treatment requirements. Thus, the choice of the particular receiver sets a rather rigid framework for the ensuing management strategy. The following issues must be considered:

1. The design of collection systems must also be reviewed in the early strategy formulation stages along with the selection of the final receiver(s).

2. The imposition of effluent treatment on selected sources is instrumental for the initial development of highly effective and enforceable wastewater management programs, even when faced with tight organizational, technical and financial constraints. Programs of this sort, which impose strict treatment only on selected sources, may be practical as far as their implementation is concerned, effective and highly economic from the overall plan point of view, they raise, however, the question as to whether selective allocation of the treatment burden is acceptable and can be justified.

3. The particular sensitivities associated with each type of waste receiver impose definite priorities, distinctly characteristic of the receiver type, in the control of particular pollutants, and define to a large extent the severity of the wastewater treatment requirements. Thus, the choice of the particular receiver sets a rather rigid framework for the ensuing management strategy and detailed action program.

4. For coastal waters, microbial pollution is the critical problem when municipal waste waters are involved. Eutrophication may also be a problem when discharging into enclosed bays or harbours.

   In coastal areas with unrestricted current movement and water renewal, primary effluent treatment and properly designed outfalls are normally sufficient to address the problem. In enclosed bays or harbours secondary waste treatment may be required so as to prevent eutrophication.

5. For lakes the major pollution problem is usually eutrophication and the critical pollutant that controls this problem is phosphorus.

   Diversion of effluents into downstream waters or on land, control at the source through the use of non phosphatic detergents etc., and use of physicochemical or tertiary treatment processes with high efficiency in phosphorus removal, are the principal control measures.

6. For rivers, the major pollution problem is the oxygen deficiency caused by the discharge of organic loads. Microbial pollution can also be a critical problem in the case of domestic wastewater discharges.

   Secondary wastewater treatment processes are often sufficient to address the organic load problem, but are marginally effective in removing microorganisms, unless properly sized waste stabilization ponds are used.

7. For land disposal, pathogen transmission is a critical problem, unless sufficient land area is available to meet the critical hydraulic and organic loading restrictions.

8. The priorities in the receiver selection, tend to be as follows: Open coast, enclosed bay or harbour, river, lake. The inherent assumption in setting the above priorities, or indeed any relevant priorities, is that the applicable water quality standards, as well as the limiting organic loading conditions for enclosed bays, can be met through ordinary control measures. Disposal on land may have a high priority depending on the suitability of the wastes (lack of toxic and persistent substances, relatively low dissolved and suspended solids, presence of phosphorus and nitrogen nutrients), on the nature of the irrigated soil, on the types of crops raised, and especially on the climatological conditions (in arid or semi arid regions the reused wastewater may constitute a valuable asset).

Finally, the formulation of detailed action program can proceed once the fundamental issues of the municipal and industrial wastewater collection system and receivers are settled, and the kind of treatment requirements established. This comprises the drafting of specific measures, which are required for achieving the pollutant reduction objectives.

CONCLUSIONS

Waste management programs must integrate the functional elements of the waste management system. Formulation of strategies can be pursued once the interrelationships between the elements of the system have been defined and the issues of final water receivers are settled.

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