WATER QUALITY AND URBANIZATION IN LATIN AMERICA

by *Carl R. Bartone**
Urban Development Division
The World Bank
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

INTRODUCTION

Rapid urbanization and industrialization in Latin America has aggravated serious wastewater disposal problems in that region. This paper reviews the main water resources and water quality management issues affecting the region, the water pollution control policies that are needed, and some of the more promising wastewater disposal options that may provide solutions for major urban areas.

URBANIZATION AND INDUSTRIALIZATION

Urbanization in Latin America and the Caribbean (as measured by population growth) is proceeding at an average annual rate of 3.6 percent, with a total urban population in 1985 of 279 million. The total population is growing at only 2.4 percent [1]. This implies that the rural population is stabilizing at around 126 million and the demographic explosion is being absorbed mainly by the cities. Recent estimates show that there are 215 cities in the region having more than 100,000 inhabitants; the population of these cities, where 44 percent of the region's people live [2], is distributed as shown in Table 1. In addition, there are some 1,200 smaller cities with 20,000 to 100,000 inhabitants. Overall, the region's urban population composes 69 percent of the total. Another feature that merits attention is the concentration of one-third of the urban population in 15 megacities of over 2 million inhabitants, as Table 2 summarizes.

The demographic explosion is being absorbed mainly by the cities.

Only 41 percent of this burgeoning urban population has access to sewer systems according to the World Health Organization's (WHO) 1985 estimates [3], and over 90 percent of the wastewater collected is discharged directly to receiving waters without treatment of any kind. Another 38 percent of the urban population is served by on-site sanitation options. This leaves 59 million urban dwellers without access to acceptable sanitation services, most of whom inhabit the low-income communities that typically surround the urban centers. Urban growth by the year 2000 means that there will be 141 million additional persons requiring service. Needless to say, sewage and excreta disposal is and will remain a leading public health and environmental problem.

Table 1. Cumulative distribution of urban population in major city centers in Latin America and the Caribbean, 1985.

POPULATION GREATER THAN	NUMBER OF CENTERS	TOTAL POPULATION (MILLIONS)
100,000	215	179
250,000	124	163
500,000	68	143
1,000,000	34	119
2,000,000	15	93
4,000,000	8	74

(Source: United Nations [2])

* The views and interpretations in this paper are those of the author and should not be attributed to the World Bank or its affiliated organizations.

0250-8060/90/$3.30 Water International, 15 (1990) 3-14

Table 2. Populations of major urban areas in Latin America, 1985 and 2000.

URBAN AREA	POPULATION (MILLIONS) 1985	2000
MEXICO CITY, MEXICO	17.3	25.8
SAO PAULO, BRAZIL	15.9	24.0
BUENOS AIRES, ARGENTINA	10.9	13.2
RIO DE JANEIRO, BRAZIL	10.4	13.3
LIMA, PERU	5.7	9.1
BOGOTA, COLOMBIA	4.5	6.5
SANTIAGO, CHILE	4.2	5.3
CARACAS, VENEZUELA	3.7	5.0
BELO HORIZONTE, BRAZIL	3.3	5.1
GUADALAJARA, MEXICO	2.8	4.1
PORTO ALEGRE, BRAZIL	2.7	4.0
RECIFE, BRAZIL	2.7	3.7
MONTERREY, MEXICO	2.5	4.0
SALVADOR, BRAZIL	2.2	3.5
BRASILIA, BRAZIL	1.7	3.7

(Source: United Nations [1])

The Gross Domestic Product (GDP) of the countries in this region grew at 6.1 percent per year during the 1970s, while industrial manufacturing increased 7.7 percent per year during the same period [4]. The major urban areas also became centers of industrial concentration, and severe industrial pollution problems appeared in most of the larger cities. During the early 1980s an economic slowdown occurred, but by 1986 GDP was again growing at 3.8 percent and industrial manufacturing at 5.8 percent [4]. As these figures suggest, notwithstanding the slowdown affecting these countries, industrial wastes continued to be discharged in growing volumes. Worse yet, the slowdown adversely affected the capacity of industry to invest in pollution control actions. Industrial wastewaters, too often uncontrolled, commonly are discharged untreated into sanitary sewers or open watercourses.

This growing concentration of people and industrial plants has created serious environmental and public health problems both in the metropolitan areas and in the river basins and coastal areas surrounding the cities. Major investments for water pollution control are needed. Over one quarter of all water resources investment goes for water supply and sewerage projects [5], but present levels of investment are insufficient. Just to maintain current levels of water quality in Latin America would require investments in treatment works and sanitary sewers much greater than the total sum currently being spent on environmental sanitation.

Major investments for water pollution control are needed.

GEOGRAPHIC CONSIDERATIONS

Realistic approaches to wastewater disposal in Latin America must take into account the geographic characteristics of the region. Four features in particular stand out: tropical climates in many areas; highlands (the altiplanto) in others; extensive arid and semiarid zones; and the coastal or riverine locations of many cities.

Most of the region's people live in tropical climates. The major exceptions to this rule are found in Argentina, Chile, Uruguay, and portions of the Andean highlands in Bolivia, Colombia, Ecuador, and Peru. This circumstance strongly affects many important aspects of sewage treatment and disposal. Perhaps the most important public health consideration is that more pathogenic microorganisms are present, and many of these exhibit both increased virulence and persistence in the tropics. Also, the average kinetic rates of biochemical processes tend to be almost double what they are in temperate zones; this vital fact affects all phases of bacterial growth and respiration, waste decomposition, waste treatment, assimilative capacity, eutrophication, and so forth.

In the Andean highlands - where concentrated rural peasant populations often live in conditions of extreme poverty, poor sanitation, and prevalent diarrheal disease - the average elevation of the populated areas ranges from 3,000 to over 4,000 meters. Here the normally low average daily temperatures slow down biochemical processes - the opposite of the above situation and one that, among other things, makes treatment processes less efficient. At the same time, because of the lower atmospheric pressure, typical dissolved oxygen saturation concentrations drop to 6-7 mg per liter, another fact that reduces treatment efficiency as well as the assimilative capacity of natural waterways.

Those concerned with environmental problems in the region must also consider distribution of the people, tillable land, and water resources - especially water resources. The reason for the latter emphasis is that while abundant humid ecosystems exist within the region, these generally have low population densities. In contrast, the 20 percent of the land that is arid or semiarid, with only 5 percent of the region's water resources, supports 60 percent of the population [6]. Therefore, use of the scarce water resources for waste disposal may severely limit their availability for other beneficial uses.

Use of the scarce water resources for waste disposal may severely limit their availibility for other beneficial uses.

Finally, the coastal or riverine locations of many urban centers may dictate waste treatment and disposal choices. A significant number of cities, including 76 with over 100,000 people, are situated along coastal zones or on river estuaries, suggesting that the option of establishing submarine outfalls is important. This point is particularly valid in the Caribbean basin. At the same time, interior cities are often located along small rivers that in colonial periods adequately served the cities' water supply and waste disposal needs, but that today have insufficient capacity for these uses. This suggests that in such cases particular consideration should be given to some form of land disposal or reuse to prevent river pollution.

WATER QUALITY AND URBANIZATION

A number of water quality problems in the region are related to the characteristics of urbanization, industrialization, and geography described above. The following are among the most important:

a. deterioration of water supply sources that every day become scarcer and more costly to develop in the face of an exploding demand;
b. inadequate disposal of wastewater - including increased domestic sewage that causes microbiological quality problems and concentrated industrial discharges that cause increased chemical contamination;
c. indiscriminate reuse of raw sewage for irrigation in arid and semiarid zones with potential public health and environmental problems;
d. increased flooding and non-point pollution related to deficient garbage collection, street-cleaning, and sewer services; and
e. rising demand for recreational opportunities by the urban population at the same time that the quality of available water resources is declining.

There is a constant increase in the number of large reservoirs being constructed.

WATER QUALITY AND WATER RESOURCE DEVELOPMENT

In addition to these problems - mostly specific to the big urban centers - a number of other water quality problems have emerged that are associated with the increased regulation and use of water resources. Among other things, there is a constant increase in the number of large reservoirs being constructed; it is estimated that the volume of the region's total water storage capacity grew at 5.8 percent annually in the last decade [5]. Given this situation, the following problems are becoming more common and may have a significant impact on urban water use:

a. eutrophication of water supply sources, especially tropical reservoirs;
b. increased breeding sites for waterborne disease vectors;
c. reduction of the assimilative capacity of regulated streams where waste disposal competes seasonally with irrigation and energy uses;
d. increased use of fertilizer and biocides in agriculture; and
e. salinization of arid and semiarid lands due to intensive irrigation projects.

WATER AND HEALTH

It is well-established that water is an important vehicle for the transmission of many pathogenic microorganisms as well as organic and inorganic toxic substances. Many of the more important transmissible diseases in the Third World can be classified [7] according to the role played by water in the chain of transmission as follows: waterborne diseases (e.g., enteric and diarrheal disease, typhoid fever, hepatitis); water hygiene diseases (e.g., trachoma, shigellosis); water contact diseases (e.g., schistosomiasis); and water vector diseases (e.g., malaria, onchocerciasis).

Enteric and diarrheal diseases represent one of the most severe health problems in the region.

As a group, the enteric and diarrheal diseases represent one of the most severe health problems in the region. They are still the number one cause of infant mortality in many countries [8]: the overall extent of infant mortality in the Americas is indicated by the data in Table 3. This situation is aggravated by low levels of potable water supply and sanitation services for both the urban and rural populations in the region. Data on regional service levels in 1985 show

Table 3. Infant mortality data for the Americas, 1979.

SUBREGION	DEATH RATE PER THOUSAND CHILDREN		PERCENTAGE OF ALL DEATHS OCCURRING AMONG CHILDREN	
	UNDER 1	1-4 YEARS	UNDER 1	1-4 YEARS
NORTHERN AMERICA	12.9	0.7	2.4	0.4
CARIBBEAN	20.5	0.71	0.5	3.0
CONTINENTAL MIDDLE AMERICA	50.9	10.4	28.4	15.4
TEMPERATE SOUTH AMERICA	32.5	1.5	11.5	1.9
TROPICAL SOUTH AMERICA	36.6	4.2	24.0	10.5

(Source: Pan American Health Organization [8])

that 71 percent of the urban population has piped water supply, another 13 percent had reasonable access to public standposts, 41 percent were connected to sewers, and 38 percent had access to on-site sanitation options. For the rural population, only 47 percent had reasonable access to safe water and 27 percent benefited from appropriate sanitation facilities [3].

At the same time, it is important to note that progress has been made in controlling these water-related transmissible diseases over the past three decades. This in turn has contributed to increased life expectancy. During the period from 1960 to 1980 the average life expectancy in the region rose from 55 to 64 years. This development, though certainly favorable, raises other important environmental health questions related to the aging profile. For example, increased industrial discharges contribute to the increasing exposure of a progressively larger group of older people to greater risks of both chronic and acute toxic effects associated with chemical contamination. However, many of the resulting chronic symptoms may not appear for many years to come.

WASTEWATER DISPOSAL ISSUES

Water Pollution Control Policies and Programs

Water pollution control programs require the evaluation of receiving water quality requirements based on prevailing and anticipated water uses and specific water quality objectives for each use. In other words, water quality must be related to integrated water resources development and is a multisectoral concern.

The methodology used must be founded on sound scientific criteria.

Developing a water pollution control program requires an approach that will lead to the establishment of a coherent set of water quality objectives for receiving waters. The methodology used must be founded on sound scientific criteria and should translate the in-stream objectives into water quality standards - usually discharge standards in the form of waste load allocations. It should also be based upon economic criteria (such as minimizing the sum of control costs plus pollution damages) and upon technical-scientific criteria (including the choice of an analytical framework) that will deal with transport and decay mechanisms of pollutant discharges in the aquatic environment and water quality transformations.

Water pollution control policies will also affect the final choice of standards. For example, discharge standards may be uniform, may vary from zone to zone of the receiving body, or may be specific to each discharger. Technology-based or minimum treatment standards may also be used in addition to effluent discharge standards. Individual treatment or regional treatment options can be considered. Each variation must be evaluated on the basis of overall technical, economic and administrative viability. Environmental and economic externalities of pollution should be considered and some form of the "polluter pays" policy applied, such as user discharge fees.

In addition to water quality objectives, discharge standards, and control policies, other essential components of a pollution control program are a monitoring system that will determine whether the standards are being complied with and a system of sanctions to deal with instances of noncompliance. If the behavior of dischargers is to be modified, pecuniary sanctions should be commensurate with the magnitude of environmental damages resulting from noncompliance.

Obviously, a program of this type requires a sound legal foundation and an institutional infrastructure supported by sufficient human, technical, and financial resources. Therefore, key matters to be considered in developing pollution control programs in the region include modernization of legislation, institutional development, establishment of the necessary analytical framework together with corresponding information requirements, and human resource development.

Water quality legislation within the region varies greatly from country to country. In the past, the tendency has been to establish classification schemes for waterways based on prevailing uses, and to set uniform in-stream standards for each class of waterway. This approach has generally failed because of its inflexibility, its failure to provide a means of relating in-stream water quality to discharges, and its inability to deal with local economic issues. Another frequent problem has been the tendency to promulgate fixed standards and pecuniary sanctions within the laws themselves, rather than through an appropriate regulatory process defined by legislation. Such detailed laws quickly become outdated and ineffective, but are difficult to modify once promulgated.

In almost all Latin American countries the concept of water quality has traditionally been identified with public drinking-water supplies. For this reason the health ministries have often been responsible for water quality control. This situation is changing as comprehensive environmental protection agencies are established in a few countries such as Brazil, Colombia, and Venezuela, and as special water pollution control agencies emerge in others such as Mexico. Separate national agencies are now usually responsible for urban water supply and sewerage programs. Rural water and sanitation programs, however, are generally still assigned to the ministries of health. Where no single agency has responsibility for water pollution control, interministerial councils may be formed to coordinate control activities, as in Peru.

Notwithstanding a rich and varied experience in Latin America with river basin management agencies, only a very few of these institutions have ever been assigned responsibility for water pollution control. Notable exceptions include the regional corporations established for the Cauca River and the Bogota River in Colombia.

All of these conditions make it difficult to attract and retain experienced professionals.

Water pollution control agencies often have institutional infrastructure problems, particularly in cases where salary scales are low, staff turnover is high and there is an apparently contradictory lack of institutional demand for specialists; all of these conditions make it difficult to attract and retain experienced professionals. Furthermore, water pollution control agencies often lack a sound financial base for their activities, and this, besides affecting staffing, may also be reflected in a lack of adequate physical facilities such as laboratories, or, where these do exist, may result in insufficient resources for the operation and upkeep of such facilities. One solution to this lack of resources is to earmark all or a portion of revenues from user discharge fees or pecuniary sanctions to be used to finance control programs.

With regard to the analytical framework, two related problems exist. One is the need to make an appropriate selection of the analytical techniques or models to apply to a specific water quality problem, and the second is to deal with the constraints imposed by limited availability or reliability of the data needed for analytical purposes. Too often the data required to calibrate, verify, and apply a water quality model are not readily available. Routine environmental monitoring of water quality for planning and control purposes is the exception,and where isolated studies have been carried out, the resulting data sets are often incomplete or inconsistent. As a result, those involved in model selection should carefully consider corresponding data requirements and should judiciously weigh the need for costly intensive data collection campaigns.

Those involved in model selection should carefully consider corresponding data requirements.

Finally there is a shortage of professional and technical personnel required for carrying out water pollution control activities in the region, even considering the reduced institutional demand. Greater priority should therefore be placed on water quality planning and management in university programs, and more extension courses and in-service training programs should be offered for engineers, economists and others practicing in this area.

In order to aid governments in their efforts to prepare and implement water pollution control projects, the World Bank has recently published a set of guidelines [9]. These guidelines provide background information on engineering, economics, financial management, legislation and regulations, and other special topics of interest to decision makers, managers, and engineers, which they may find useful for solving their problems and protecting the water environment.

Investment Capacity

In recent years, a combination of economic circumstances has adversely affected the investment capacity of water and sewage agencies in the region. While the region's Gross Domestic Product grew at annual rate of 6.1 percent during the decade of the 1970s and manufacturing grew at 7.7 percent per year, the recent worldwide economic recession subsequently caused these rates to fall to -6.5 percent and 0.4 percent , respectively, during the period 1980-86 [4]. In that period, per capita GDP dropped from US$2,288 to US$2,140. By comparison, average foreign indebtedness in Latin America in 1986 stood at US$975 per capita. The sharp downturn is reflected in gross domestic investment which dropped from an average of 23.2 percent of GDP during the 1970s to only 15.6 percent during 1984-86 [4]. This situation will necessarily affect national water supply and sewerage investment programs, unless the sector can achieve self-financing. According to a WHO survey of selected countries [3], average urban water consumption in Latin America in 1985 was 200 l/c/d for household connections, and the average tariff was US$0.38/m³. The latter figure appears high based on World Bank information, but can be used to estimate an upper limit on revenues generated. With 71 percent of the urban population connected to municipal water supply systems, the maximum revenues generated in 1985 would be US$5.5 billion. Even if this upper limit was reached, the sector as a whole would still not be self-financing. Serous concerns persist over investment needs as well as debt service and the resource needed for the efficient operation and maintenance of existing assets.

The sector as a whole would still not be self-financing.

Recent WHO [3] estimates of sector investment requirements during the period 1986-90 for Latin America indicate that US$20 billion will be needed to meet the water supply and sanitation coverage goals established by the governments. Of this, it is expected that one third of the investment funds will come from external financing, and the rest from domestic financing. (World Bank sector lending during 1983-87, for example, was US$856 million.) The investment needs for urban sanitation alone are expected to be US$8.3 million during the same period.

On the optimistic side, sanitation services were provided to an additional 60 million urban dwellers from 1981-85, partly through the use of low-cost technology. (Per capita costs of sewers dropped from US$165 to US$150 between 1980 and 1985.) If that pace can be maintained it should be possible to meet the 1990 target of 90 percent coverage with a mix of sewers and on-site sanitation options. However, there is little room for complacency since urban growth trends indicate that another 200 million will need to be served by the year 2000. Because of parallel increases in water supply coverage, the volume of wastewater to be handled should double during that same period.

Partly for the above reasons, various interrelated financial, economic and technological issues in the area of wastewater collection, treatment, and disposal are receiving increased attention in Latin America. These include the following:

a. Water and sewerage companies should achieve a greater degree of self-financing through the application of adequately designed tariff structures.
b. Water conservation measures should be promoted and implemented to minimize the volumes of sewage flows to be disposed of.
c. Wastewater disposal systems need to be optimized using cost-efficient technology, eliminating unjustified treatment, and making maximum use of the assimilative capacity of receiving waters and land treatment.
d. Industrial wastewater discharges should be kept out of municipal sewers unless adequately pretreated prior to discharge.
e. Wherever possible, without endangering public health, reuse alternatives designed to convert wastewater into an economic resource should be considered.
f. Conventional design and construction criteria and standards for sewers and treatment systems should be carefully reviewed and revised to achieve greater economies.
g. Non-sewered disposal options for low-density, low-income urban fringe areas need to be demonstrated, along with the possibilities for community participation in construction and operating activities that could further lower costs.

While some of these approaches might be considered controversial in developed countries, and while their implementation would require that design engineers modify their routine conservative approaches, they represent the best hope for significantly extending wastewater and excreta disposal services to the large segments of the urban population in Latin America yet to be served, and for providing a significant improvement in water pollution prevention and control in the region.

WASTEWATER DISPOSAL ALTERNATIVES

Several promising options for improving waste water disposal practice in developing countries are being investigated by a joint program of the World Bank and the United

Their implementation would require that design engineers modify their routine conservative approaches.

Nations Development Programme (UNDP) in support of the International Decade for Water Supply and Sanitation. Special projects on low-cost urban sanitation and on waste management and resource recovery have been developing and demonstrating appropriate technology solutions, and evaluating approaches for their large scale application. Many of these demonstration efforts have occurred in Latin America. Special emphasis has also been placed on the preparation of training materials and the establishment of an international training network, including a regional subnetwork for Latin America.

The remainder of this paper will look at several of the options of particular relevance to the region. These include the use of low-cost technologies for wastewater treatment, sewers and on-site sanitation, submarine outfalls for ocean disposal, water quality management planning methodologies, and wastewater reclamation and reuse for irrigation.

Low-Cost Technologies

Existing conventional sewer systems are often limited for historic and financial reasons to serving the older inner-core city areas and the newer middle and upper class residential areas of the cities. However, most of the 59 percent of the urban population lacking sewers live in low-income fringe areas. While many of these people may receive water through household or patio connections, they often lack even basic sanitary facilities for excreta disposal or graywater drainage.

New approaches . . . are needed.

Because the provision of conventional systems for these urban fringe areas exceeds the investment capacity of many large cities, only drastic revision of design criteria and sharp reduction of construction cost is likely to offer hope of providing even minimal levels of service to these areas. New approaches to sewer design, on-site sanitation options and low-cost treatment technologies are needed. Also, a strategic sanitation planning methodology is needed to assist authorities in determining where and when low-cost sanitation options are appropriate.

(a) Sewer Design and Construction

One innovative sanitary sewer project has been constructed in Cochabamba, Bolivia, a city of 240,000 inhabitants. New design criteria have been applied by the local water and sewage service in order to reduce sewer diameters, slopes, and manholes, thereby cutting costs. Additional economies were achieved by designing modular pumping stations. The collected effluents are to be treated in waste stabilization ponds and subsequently reused for irrigation. This integrated unconventional approach resulted in conventional standards of service for the population of Cochabamba at greatly reduced cost.

The above approach is also being applied in Brazil where it is referred to as "simplified sewerage" and a design manual has been published [10]. To achieve further economies in design, simplified sewers are often used in combination with low-volume flush toilets (using 4-5 liters per flush instead of the conventional 15 liters). Also, manholes are replaced by small cleanouts to the greatest extent possible. In Brazil costs have been reduced by as much as 33-46 percent with such systems [11].

Another approach is the use of small-bore sewers for conveyance of settled sewage from septic tanks or interceptor tanks. Sewers are typically plastic pipes of three to four inch diameter, and may be designed for variable gradient conditions. They can be used effectively in combination with pour-flush or low-volume flush toilets, and can serve to upgrade existing septic tank services. Compared to conventional sewerage, small-bore sewers can be half the cost to construct and operate, and yet provide a similar level of service. Variations of this technology were pioneered in Australia, Nigeria, the United States and Zambia, and a design manual has been published by the UNDP/World Bank Decade Program [12]. Small-bore sewers are being demonstrated in Brazil through a UNDP supported project, and could have application in most countries of the region.

(b) On-site Options

Even the above modified sewerage approach is not affordable for many low-income communities. New ideas have increasingly been put forward to explore very low-cost on-site options that are suitable for areas with low population density, well-drained soils, and low water consumption rates. The UNDP/World Bank low-cost sanitation program has supported a number of demonstration projects around the world and published a series of technical reports.

In Latin America, several examples exist of such approaches [11]. Construction of ventilated pit latrines, using community self-help labor, have been demonstrated in slums of Guayaquil, Ecuador, where sewers are not technically or economically feasible. The commercial production of pour-flush toilets utilizing only three liters of water is underway in Brazil, Colombia and Peru. Some of these models can be sequentially upgraded to connect to piped water systems. Installation of lined pit latrines emptied by means of vacuum pump trucks or carts is being demon-

Commercial production of pour-flush toilets utilizing only three liters of water is underway.

strated in northeast Brazil, where prefabricated units are being installed with community self-help labor. In one such project the user amortizes the cost of the latrine (about US$60) over a five-year period and pays a monthly service charge to the water and sewerage company for latrine cleaning and maintenance. Up to one-third of the payment can be made in kind through contributions of manual labor and cement.

It is important that these and other proposals and demonstration projects be carried through to completion and be subjected to complete evaluation regarding their technical and sanitary soundness, their economic feasibility, and their acceptance by the communities involved. The future work of the UNDP/World Bank Decade Program will be to evaluate these software components and to investigate the potential for application of these options on a massive scale in large urban fringe areas with low population densities. If solutions of this kind can be shown to work, and if they prove acceptable to low-density urban fringe communities, improved sanitation may finally be brought within reach of many millions of the urban poor in places where present sanitary services are inadequate or lacking.

(c) Wastewater Treatment

Where sewers exist, the main problem is still provide for the safe discharge of the collected wastewater, which is on the order of 40 million cubic meters per day. As mentioned, less than 10 percent of sewered wastewater receives treatment in the region. Added to this is the poor experience with the operation and maintenance of existing treatment plants. In one country which shall remain nameless, a survey revealed that 80 percent of over 230 wastewater treatment plants installed were not functioning because of operational problems. In another country, 33 of 42 mechanical treatment plants were encountered out of service by a Bank survey. To achieve any significant expansion of treatment capacity will require the use of lower-cost, robust treatment plants or processes, increased attention to financial and operational issues, and maximum utilization of any advantageous natural conditions which may exist.

Among the promising treatment processes that can be used to better advantage in the tropical zones are waste stabilization ponds. They are economic, robust and can achieve practically any desired level of water quality by adding additional ponds in series to increase detention times. Only where land costs are prohibitive should ponds be ruled out. Even near highly urbanized areas it may be possible to justify the use of ponds compared to conventional mechanical plants [13]. Ponds have been used extensively in several countries already, including Cuba, Mexico and Peru. The largest pond facility in Latin America is the Mexicali system with 180 hectares of ponds treating a wastewater flow of 1.2 cubic meters per second.

80 percent of over 230 wastewater treatment plants installed were not functioning.

Important research on pond evaluation under different climatic conditions is being conducted in Brazil, Chile, Mexico, and Peru. Investigations to date have confirmed that under tropical conditions pond loading rates can be significantly higher than for temperate zones, and that pathogen removal rates in well designed multicell pond systems are high enough to obviate the need for effluent disinfection. Ponds with more than 25 days detention time in hot climates should produce an effluent suitable for unrestricted irrigation reuse.

Anaerobic treatment is also receiving attention in the region. Pilot plants (primarily upflow anaerobic sludge blanket reactors) have been built and evaluated for domestic sewage treatment in Brazil, Colombia and Peru with good results. Nine such plants are now in operation around Curitiba, Brazil. Simple fixed-film anaerobic reactors are also being demonstrated for small communities.

Other technologies which merit a closer look in the water short areas include land treatment, especially overland flow, engineered wetlands, and soil-aquifer treatment systems.

(d) Strategic Sanitation Planning

In any given large city it is unlikely that a single solution can address the needs of all the population. Some parts of the city may have conventional sewerage, other parts could be served by simplified or small-bore sewers, yet others may be able to afford on-site systems, and some low-income areas may have only be able to afford incremental improvements upon traditional or informal means of sullage or nightsoil disposal. Thus to meet the needs and capacities of different segments of a city, an alternative planning process is required to the conventional master plan approach which typically only considers complete sewerage.

The failure of past planning approaches is seen in numerous cases where sewers have been built to cover limited areas of a growing city, but only a small percentage of the population in the service areas can afford to connect. Since assumed connection rates are not met the system becomes a financial failure, and plans for system expansion have to be postponed or abandoned. Thus the master plan often ends up as a dusty, rapidly outdated report on a shelf.

A strategic sanitation planning process should, in contrast, evaluate service needs versus service standards, population density, affordability and user preference, and select a spectrum of sanitation technology options which best meet the needs and capacities of different segments of the city at any given time. Continual upgrading from one service level to a higher one should be implemented as community capacities and expectations rise. Therefore, designs should be chosen which permit the greatest possible level of upgrading. The objective of such a process is to improve service levels for all urban dwellers in a sustainable manner. A great deal of research is needed in this area to develop and verify such dynamic and pragmatic planning tools.

Wastewater Disposal in Coastal Areas

Of the 215 cities in Latin America and the Caribbean with more than 100,000 inhabitants, 76 cities with some 58 million inhabitants are located along the seacoast or on river estuaries. The number of coastal cities increases many-fold when cities of 20,000 to 100,000 inhabitants are included.

A common practice in the coastal cities is to discharge untreated wastewaters to the nearest or most convenient water body, and sometimes only secondary considerations are given to the ensuing environmental consequences. Indeed, raw sewage discharges have often occurred very near bathing beaches, as happened in the case of the world famous Ipanema Beach in Rio de Janeiro, and as currently happens at or near the beaches of Montevideo, Lima, and most other coastal cities of the region. Such discharges entail potential health and ecologic hazards; they also create esthetic problems and may cause economic losses associated with reduced tourism.

This is far beyond the capabilities of conventional secondary treatment.

In view of the vastness of the oceans, it is only logical that the residual liquid wastes of coastal cities should be discharged to the adjacent ocean waters. Nevertheless, in seeking to avoid the above-mentioned problems, a question arises as to whether the most appropriate means consists of conventional waste treatment, use of ocean outfalls, or a combination of the two. In an uncomplicated open-ocean situation, the approach of constructing long ocean outfalls and providing pretreatment for floatables offers many advantages over conventional solutions using secondary waste treatment with discharge close to shore. For example, ocean outfalls designed to properly eliminate wastewaters can consistently achieve immediate dilutions on the order of 100 to 1 during the first few minutes of discharge, thereby reducing the concentrations of organics and nutrients typical of domestic wastes to levels that have no adverse ecological effects. This is far beyond the capabilities of conventional secondary treatment. Also, subsequent mortality of bacteria in the hostile ocean environment can further reduce the concentrations of pathogens to levels comparable to or below those achieved by chlorination of secondary effluents.

For typical urban waste flows the lifetime cost differential between conventional secondary treatment on the one hand and conventional primary treatment with ocean outfalls on the other will often favor the latter course. This conclusion is based on the knowledge that properly designed long ocean outfalls (three to five kilometers in length) discharging into tropical waters at depths greater than 20 meters will almost always meet both total and fecal coliform standards for bathing beaches. Limiting pretreatment to the removal of floatables only would make the comparison even more favorable for the ocean outfall alternative. Also, the recent use of more economical plastics in the construction of outfalls further enhances the viability of this alternative for waste disposal, especially for communities of small to intermediate size.

The results of a survey carried out by the Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS) of the Pan American Health Organization indicate there are 79 existing and planned outfalls of lengths of 500 meters or greater (44 longer than 1,000 meters) in the region [14]. The great majority are located in Brazil, Mexico, Puerto Rico and Venezuela. Of them all, the Ipanema Outfall is perhaps the best known, and its receiving waters have been extensively monitored [15]. This outfall services the southern zone of Rio de Janeiro, maintaining a present sewage flow of six cubic meters per second; its design flow, projected for the year 2000, is 12 cubic meters per second. It has a length of 4,325 meters, a diameter of 2.4 meters, and a diffuser 400 meters long (with 178 ports 17 centimeters in diameter) that discharges at a depth of 28 meters. Continuous water quality monitoring, conducted by the local water and sewage authority, has demonstrated significantly improved conditions since inauguration of the Ipanema Outfall in September 1975. Aside from coarse screening to protect the pumps, no wastewater treatment or chlorination is provided for the Ipanema Outfall effluent.

Chile and Venezuela have numerous outfalls of less than 1,000 meters. However, most of these are merely extensions of the sewer system and have not been designed according to modern criteria in order to optimize initial dilution of the effluent.

In general, dissemination of modern outfall design technology, which is presently limited to a few countries, is needed in the region. To this end, the UNDP/World Bank program has published a manual on wastewater management for coastal cities [16] that treats the ocean disposal option in detail. Also, CEPIS is preparing a manual on the conceptual design of ocean outfalls that will address the

Dissemination of modern outfall design technology . . . is needed in the region

interests of national water and sewage institutions within the region.

Application of Water Quality Management Technologies

Water Pollution problems within the region range from severe dissolved oxygen problems - as evidenced by extensive reaches of rivers with zero dissolved oxygen levels such as the Salt River in Argentina and the Bogota River in Colombia - to bacteriologic contamination as in the Rimac River in Peru, to contamination with toxic substances as for example Brazil's Paraiba River. One key to solving these problems is development and dissemination of policy, planning, and control methodologies for water quality management. Within the context of the limited investment resources and competing priorities already discussed, it is evident that the assimilative capacities of the natural bodies of water involved must be utilized, and that the imposition of blanket levels of waste treatment without taking cognizance of this assimilative capacity may result in excessive investment requirements. All this implies a need to develop sound and efficient water quality planning methodologies with which design criteria can be directed toward optimizing water use and protecting public health.

Mathematical models, which related waste inputs to water quality in the receiving water body, can be employed to evaluate alternate engineering plans for control and management of water quality. Solutions that involve varying degrees of treatment (no treatment may be a legitimate option), relocation of the waste discharge points, low flow augmentation, in-stream reaeration, and regional treatment systems versus multiple plants are some of the specific alternatives whose influence on receiving water quality can be assessed by the application of water quality models.

The factors that influence the degree of complexity of the modeling effort include the water quality problem at hand, the characteristics of the water body, the availability of data on present and past water quality and waste discharges, the public health and environmental risks associated with the discharged contaminants, the range of alternative strategies and options available, and the time, funds, and qualified staff available.

The climatic characteristics of the region require special consideration in the development and application of mathematical models. For example, the construction of artificial multipurpose reservoirs for potable and industrial water supplies, irrigation water, and hydroelectric power has accelerated in the region over the years. However, these reservoirs have generally been created without regard to the potential for eutrophication. The only simplified models available for the evaluation of eutrophication in lakes and reservoirs were developed from data on temperate lakes, and it has been found that these methodologies are not adaptable to the predominantly warm-water lakes of the region. A regional research project, coordinated by CEPIS, is developing simplified methodologies for the evaluation of eutrophication in warm-water lakes and reservoirs. Nine countries in the tropical and semitropical areas of the region are participating in this research through investigations of 26 lakes [17]. The final results will provide a tool not yet available for the planning of future reservoirs as well as for estimating the extent of corrective measures required to alleviate present nutritional pollution problems.

These reservoirs have generally been created without regard to the potential for eutrophication.

A great deal of skepticism exists about the practical usefulness of planning and modeling methodologies, but there are a number of successful case histories in Latin America - such as the Maipo River in Chile, the Cauca River in Colombia and the Guanabara Bay in Brazil [18]. Similar experiences exist in Argentina, Mexico and Venezuela. They are valuable illustrations of what can in fact be done and have served as examples for other countries. In general, the use of simple models with limited data requirements should suffice for planning purposes. Complex models that may outstrip local information and basic understanding of hydrologic-chemical-biological processes should be avoided or used with caution.

Wastewater Reuse

The large-scale reuse of untreated domestic sewage waters for irrigation is commonplace in many arid and semiarid zones of Latin America, and often occurs without effective sanitary controls. This practice may pose substantial health risks for farm workers and for the population consuming agricultural produce from such areas. High rates of parasitosis tend to be associated with uncontrolled reuse, and outbreaks of enteritis, other diarrheal diseases, typhoid, and hepatitis are suspected to have been caused by raw sewage irrigation of vegetables. However, where adequate treatment and control is provided such risks are minimal. Examples of large-scale wastewater reuse for irrigation, some with raw sewage reuse, include the following:

a. In the Santiago Metropolitan Area (population 4.5 million), a total sewage flow of 9 m^3/s is discharged without any treatment to three water courses crossing the city that in turn feed numerous canals irrigating an area of about 62,000 ha, including the irrigation of vegetables for raw consumption. In the summer season, the wastewater is the only water source available for irrigation of some zones. The widespread practice of irrigating vegetables with untreated sewage or with polluted river water has been implicated in the unusually high typhoid morbidity rates in Santiago [19]. The World Bank is currently supporting investments in wastewater treatment for Santiago in response to concerns over the reuse of raw sewage.

Evidence of toxic contamination of groundwater has recently been identified.

b. Mexico City's wastewater irrigates some 90,000 hectares of agricultural lands in the adjacent Tula valley with raw or mixed sewage. This scheme has been in operation since the early 1900s. Edible crops from this reuse sites have been found contaminated with fecal coliforms, and evidence of toxic contamination of groundwater has recently been identified. Planned wastewater irrigation projects in Mexico will extend to 250,000 hectares in total within a few years. Within Mexico City, landscape irrigation with secondary treated, disinfected effluents is practiced, including Chapultepec park and the main Avenues of the city.
c. In Peru, 31 reuse projects have been identified along the country's desert coast, many of which use waste stabilization pond effluents. There are also some uncontrolled reuse sites in and around Lima affecting about 2,000 hectares of vegetable crops. Peruvian authorities are currently planning to reuse three cubic meters per second of treated effluents to irrigate 4,000 hectares of desert land to the south of Lima.
d. Mendoza, Argentina irrigates 5,700 hectares around the city with effluents from several small wastewater treatment plants.

As some of these examples suggest, the heavy concentration of populations in arid and semiarid zones of the region gives rise to an economic demand that sometimes creates spontaneous and indiscriminate reuse. The responsible public health authorities must anticipate these economic pressures, and must plan for and implement adequate sanitary control measures for the practice of safe reuse.

One of the main priorities of the UNDP/World Bank project for waste management and resource recovery has been to investigate the public health consequences of irrigation reuse and evaluate the effectiveness of technical and policy options for controlling risks [19]. This work represents a major contribution to an international effort. A consensus on new public health guidelines for irrigation with reclaimed wastewater was reached among the main international agencies, including WHO, UNEP, FAO, UNDP and the World Bank, and the guidelines were formally endorsed by a WHO Expert Committee and have been published by WHO [20]. Several Latin American countries are now studying the convenience of adopting these guidelines as part of their national standards.

The health, socioeconomic, and environmental benefits resulting from safe, controlled reuse projects are many; they include the recovery of arid lands for agriculture, creation of employment and settlement opportunities, increases in agricultural productivity, creation of recreational opportunities and amenities through establishment of parks and greenbelts, and development of a viable alternative to other more costly forms of sewage disposal and their corresponding pollution problems. Collectively, these benefits suggest that reuse can offer one way of helping finance sewage works. A major precondition for realizing such benefits, however, is close multisectoral coordination between national water resources policy makers, municipal sewerage authorities and agricultural users, as well as an appropriate allocation of project costs among them.

One common stumbling block to increased industrial reuse is the undervalued price of water to industry.

Finally, reuse of treated municipal wastewater by industry is another area being closely studied by several Latin American countries, particularly Brazil and Mexico. Industrial cities like So Paulo and Mexico City are finding it increasingly difficult to meet industrial water demand and will be forced to increased reuse. A well known example of an industrial reuse scheme run by a private industrial association has operated in Monterrey, Mexico for many years. One common stumbling block to increased industrial reuse is the undervalued price of water to industry because of subsidized municipal tariffs. Once they have to pay the real cost of the water they consume, many more industries in water scarce areas are likely to follow the Monterrey example.

SUMMARY

Water quality and urbanization are strongly interlinked in Latin America. Urban water demand is increasingly difficult to satisfy given water pricing policies that fail to recover costs, deteriorating water quality due to both urban and agricultural wastes, and the geographic and hydrological characteristics of the region.

This paper discusses water resources management and water pollution control policies and programs, and analyzes wastewater disposal issues and investment requirements in the region. Finally, several promising options for improving wastewater disposal practice in the region are examined, such as: the use of low-cost technologies for wastewater treatment, sewers and on-site sanitation, submarine outfalls for ocean disposal, water quality management planning methodologies, and wastewater reclamation and reuse for irrigation.

The dissemination and routine application of approaches suggested may provide the only practical solutions for many major urban areas, not only in Latin America but also in other regions of the Third World.

REFERENCES

1. United Nations. *The Prospects of World Urbanization: Revised as of 1984-85.* New York, 1987.
2. United Nations. *Estimates and Projections of Urban, Rural and City Populations, 1950-2025: The 1982 Assessment.* New York, 1985.
3. World Health Organization. *The International Drinking Water Supply and Sanitation Decade: Review of Mid-Decade Progress (as at December, 1985).* Geneva, 1987.
4. Inter-American Development Bank. *Economic and Social Progress in Latin America: 1987 Report.* Washington, D.C., 1988.
5. Economic Commission for Latin America. *The Water Resources of Latin America and their Utilization.* ECLA Report No. 53, 1985.
6. Economic Commission for Latin America. "Water Management and Environment in Latin America." In: *Water Development Supply and Management,* Volume 12, Pergamon Press, Oxford, 1979.
7. McJunkin, F. E. *Water and Human Health.* U.S. AID, Washington, D.C., 1982.
8. Pan American Health Organization. *Health Conditions in the Americas, 1977-1980.* PAHO Scientific Publication 427, Washington, D.C., 1982.
9. Palange, R. C. and A. Zavala. *Water Pollution Control: Guidelines for Project Planning and Financing.* World Bank Technical Report No. 73, Washington, D.C., 1987.
10. National Housing Development Council. *Manual de Saneamento: Redes de Esgotos Simplificados.* UNDP/World Bank Project INT/81/047 (draft manuscript), 1985.
11. Bartone, C. R., editor. *Alternativas de Tecnologia de Saneamiento de Bajo Costo para Zonas Urbanas Marginadas.* CEPIS, Lima, Peru, 1987.
12. Otis, R. J. and D. D. Mara. *The Design of Small Bore Sewer Systems.* TAG Technical Note 14, World Bank, Washington, D.C., 1985.
13. Arthur, J. P. *Notes on the Design and Operation of Waste Stabilization Ponds in Warm Climates of Developing Countries.* World Bank Technical Paper No. 7, Washington, D.C., 1983.
14. Salas, H. J. *A Manual for the Planning and Conceptual Design of Submarine Outfalls in Latin America and the Caribbean.* CEPIS, Lima, Peru (draft manuscript), 1985.
15. Companhia Estadual de Aguas e Esgotos. *Relatorio de Actividades, 1982.* Divisao de Operacao e Tratamento, Rio de Janeiro, 1982.
16. Gunnerson, C. G., editor. *Wastewater Management for Coastal Cities: The Ocean Disposal Option.* World Bank Technical Paper No. 77, Washington, D.C., 1988.
17. Salas, H. J. and G. Limon. *Desarrollo de Metodologias Simplificadas para la Evaluacion de Eutroficacion in Lagos Calidos Tropicales.* CEPIS, Lima, July, 1986.
18. Coelho, V. B. M. and M. R. Fonseca. "Management of Water Quality in Guanabara Bay, Bra." In: *Water Management and Environment in Latin America,* 12:221-237, 1979.
19. Shuval, H. I., A. Adin, B. Fattal, E. Rawitz and P. Yekutiel. *Wastewater Irrigation in Developing Countries: Health Effects and Technical Solutions.* World Bank Technical Report No. 51, Washington, D.C., 1986.
20. World Health Organization. *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture.* WHO Technical Report Series No. 778, Geneva, 1989.

LAKE CHAD PROCEEDINGS AVAILABLE

The Proceedings of the International Seminar on Water Resources of the Lake Chad Basin: Management and Conservation, held from 3-5 June 1989, at N'Djamena, Chad has gone to press and will be available in April 1990 for US$20 per copy.

It is to be available in separate English and French versions, and advance orders may be placed with:

Executive Secretary
Lake Chad Basin Commission
B.P. 727
N'Djamena
CHAD

This publication contains 29 papers by various authors on diverse aspects of the water resources of the Lake Chad basin and should be invaluable to scientists, engineers, etc. Please place orders as early as possible as the supply will be limited.