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Expanding Water & Sanitation Systems

Moderator: *Mr. Geoffrey Read, Principal Municipal Engineer, East Asia & Pacific Urban Development Sector Unit, The World Bank*

Speakers: *Mr. Chanchai V. Panyakij, Director, Water Quality and Management Division, Department of Drainage and Sewerage (Thailand)*

Mr. Klaus Dieter Neder, Superintendent, CASEB (Brazil)

Mr. Agus Gunarto, Sanitation Department, City of Malang (Indonesia)

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Introductory Notes

Combined versus Separate Collection Systems: Where should the Bank's Sanitation and Wastewater Treatment Policy be Heading?

The combined wastewater collection and treatment system: In many developing countries municipal agencies have utilized the drainage network as a means of collecting wastewater from households. A common feature in several East Asian countries, for example, is for homeowners to connect their septic tanks to the tertiary drainage channels in the neighborhood. With the septic tanks themselves being poorly constructed (i.e. usually without soakaways), the municipal drainage networks have invariably been converted into de facto sewers.

With increased population densities, these drains are carrying very high pollution loads, and there has been a visible public outcry against pollution caused by untreated wastewater. In terms of the sectoral program, when sanitation, or general urban environmental investments are proposed by the Bank's clients for financing, our financial and institutional support is usually requested for rehabilitating and expanding the existing combined systems. Private investors have also often perceived downstream business opportunities, and approached city administrators with highly capital-intensive BOT (build-operate-transfer) proposals for treating wastewater generated through the combined systems.

The separated sewage collection and treatment system: There is general agreement that separate sewerage systems -- based on the conventional design norms of western industrialized countries -- are impossible for many of the less developed countries to afford. However, an alternative paradigm, developed in Brazil and experimented with in Pakistan and Indonesia has successfully expanded sewage collection and treatment infrastructure at significantly lower investment costs than the conventional systems. The municipality continues to be responsible for managing the urban stormwater drainage infrastructure.

The two models have very different institutional implications. In the combined model the municipal agency (or a subsidiary firm) retains the responsibility for planning and implementation of the program. In the separated model, the water utility (or the community) undertakes the responsibility of collecting and treating liquid wastes generated by households.

Speakers at the Water Forum: This session will provide an opportunity for participants to hear from speakers familiar with the two alternative approaches. The first speaker, Mr. Chanchai Panyakij, has been responsible for planning and developing the wastewater infrastructure for Bangkok Metropolitan Area, which is a typical example of an East Asian city's combined system. The second speaker, Mr. Klaus Neder, of the Brasilia State Water Company (CAESB), has by contrast, been intimately involved with a significant expansion of the condominial (i.e. intermediate sewage collection and treatment system) in the peri-urban areas of that city. The third speaker, Mr. Agus Gunarto, has on his own initiative, developed a condominial-type sewerage system in Indonesia with active involvement of the beneficiaries in the city of Malang, Indonesia.

After hearing the presentations, we hope to generate discussions on the following themes:

- What are the cost implications for the two models?
- As far as Bank policy on sanitation, when is the combined system preferable to separate systems, and when is it not?
- How can resources be generated to finance, operate and maintain these systems?
- What are the demand-side implications? If, for example, consumers get accountable and efficient water utilities, would the willingness to pay for sewer connections be assured?
- What are the institutional implications? Is it institutionally easier to operate and maintain a combined or a separated network? Which of the two offer better incentives for sustainable operations and maintenance?

Vijay Jagannathan
Session Leader

Biographies

JOHN BRISCOE

Mr. Briscoe is Senior Water Advisor in charge of leading the Bank's work on water resource management and integrating the efforts in the different water-using sectors, including water resources, irrigation, hydropower, water environment and water and sanitation. Since joining the World Bank, he has been Senior Economist in the Brazil Department and Chief of the Water Supply & Sanitation Division.

Prior to joining the Bank, Mr. Briscoe's major work experience included, Water Resource Planner with the Department of Water Affairs in South Africa; Epidemiologist with International Center for Diarrheal Diseases Research in Bangladesh; Water Resources Research Fellow, Harvard University; Water Resource Engineer, Government of Mozambique, Associate Professor of Water Resources, University of North Carolina at Chapel Hill.

AGUS GUNARTO

Mr. Gunarto is the winner of a silver award in the *Far Eastern Economic Review*'s first annual Asian Innovation Award for his integrated sewage treatment plant for households in 1987. He is employed in the local government and sanitation office in Malang, East Java.

KLAUS NEDER

Mr. Neder is head of the Sewerage Design and Construction Department, at the Water and Sewerage Company of Brasilia (CAESB), responsible for the implementation of the Condominial program in Brasilia. He is a Civil Engineer.

GEOFFREY READ

Geoffrey Read is a Principal Municipal Engineer in the World Bank's East Asia and Pacific Urban Development Unit where he team leads urban, water and wastewater projects in China. Upon the joining the Bank he worked for the UNDP-World Bank Water and Sanitation Program in Africa and Asia. He worked in consulting and industry prior to joining the Bank, and holds degrees in civil engineering, public health engineering, and business administration.

Condominial Sewerage Systems in the Federal District of Brazil

SUMMARY

Eng. Klaus D. Neder,
Superintendent of the Expansion of Sewerage Systems at the Water and Sewerage Company of Brasilia.

INTRODUCTION

Caesb, the company responsible for the water supply and sewerage for Brasilia, a 2.000.000 inhabitants city, capital of Brazil, aims to deliver basic sanitation to 100% of its urban population. Developing sewerage systems that will enable to meet the demands made by constantly increasing urbanization is a great challenge for the company, mainly because of the lack of resources that is characteristic of developing countries. This situation has forced the planners to look for low cost solutions, as the only way to achieve the 100% coverage mark. The creation of sewerage systems, including the treatment of the sewage, using technologies adapted to today's Brazilian reality, is one of the main objectives of Caesb. In recent years the company has been applying and developing sewerage systems that try to make the most of the available resources.

In that way, Caesb has developed a methodology for the development and construction of sewerage systems, which has led to the servicing of large sections of the city population in a short space of time. At the same time, the technology has kept in mind its mission to optimize current projects and works, always keeping implementation costs as low as possible. For this reason Caesb adopted the condominial sewerage system, developing a procedure for its implementation, that includes all stages of the undertaking: planning, financing, bidding, tariffs and technical aspects, right up to the actual implementation. All this has had to be done within the restrictions of time and resources, without loosing sight of the fundamental questions about the installation of the system.

THE CONDOMINIAL SYSTEM IN BRASILIA

The Condominial System of sewage collection has been adopted by Caesb because, as described in the bulk of this paper, it provides a low cost wastewater collecting network, and at the same time, makes community participation a key part of the implementation process. With this participation and the use of appropriate technologies, it can lead to engineering solutions that fit in with existent resources, allowing to achieve the 100% aimed coverage. At Caesb, in Brasilia, the system was used as a pattern solution, covering all areas of the city, with the same rules, independently of the economic situation of the population covered.

At Caesb, users' participation occurs in all the phases of the process, from its installation to the operation of the system. The participation begins with the decision of the engineering solution to be adopted for the condominial branch, sharing it with the technicians of Caesb, reaching the participation in the costing of the enterprise. For this, Caesb has introduced a tariff policy that tries to reflect the characteristics of the condominial system, both in terms of the charge for connection to the system and in relation to the tariff for the use of the system. On the one hand, the connection charge aims to reflect the real cost of installing the condominial branch, as chosen by the users. On the other, the tariff for the use of the system tries to reflect the user's participation in its operation, since in the internal branches the responsibility for maintenance lies with the users, giving them the right to a reduction in the tariff paid.

CAESB'S METHODOLOGY AND RESULTS

In the methodology employed by Caesb there is no distinction made between the project phases and the installation work: it is just an integrated process. This is because the location and exact depth for the public networks will only become known after community mobilization, when the executive project for the condominial branches is made. This way, the executive project is developed throughout the construction of the networks, when a project team stays on site, making the location and the depth of the system compatible with the condominial branches defined by the inhabitants. All physical interference's are considered by the planners themselves, who then adjust the plan and details of the networks in accordance with the overall conception of the system.

The procedure now adopted by Caesb is the result of more than 8 years of using the condominial system in Brasilia, not as a special project, but as the normal solution employed by the company. During this time the system was continually developing, allowing the city to reach the highest rates of sewage collection service in the whole country. The methodology proved to be capable of meeting the objectives of the company, allowing it to service a project population of 1 134 574 (with about 121 000 homes already linked to the system), through the installation of 1 328 498 m of condominial branches and 667 485 m of public networks. The average per capita cost was approximately US $27 (Exchange rate R$1,20 = US1,00). These costs, along with the use of appropriate technology for sewage treatment, have allowed the installation of complete sewerage systems at a cost of about US $65 per inhabitant serviced, which probably represents the lowest cost likely to be found in a public works project. The whole condominial program along its 8 years life time, was financed by several national or international agencies, using the normal available financing lines witch exist for conventional sewerage systems. This task was made easier due to the low cost. One must remember that Caesb has got a fast partial return of the investments cost's, due to the user's payment of the connecting fee, witch represents around 25 – 30% of the cost of the system. This fee is normally paid divided in 10 monthly quotas, and allows new investments in the system.

LESSONS LEARNED

During its years of putting the condominial system into practice on a grand scale, perhaps the most important lesson that Caesb has learnt is that its success depends on involving all the areas of the company that are connected to the task in hand, thus getting a result that truly addresses the objectives of the system. This involvement demands complete understanding of the system by everybody in the project, so that each one has a precise idea of their importance in the system and of the contribution that their work will make to the process as a whole.

It is also important to remember that the implementation of a condominial system doesn't just involve the participation of the community and of a community mobilization group, but that it also involves a great number of professionals within the company, who make the enterprise viable. Caesb has tried to root the philosophy of the condominial system in the daily life of the company, getting the various areas of the company to involve themselves in the experience of making the system work. So the work was carried out using the normal structure of Caesb, trying to avoid the creation of an isolated group linked to a specific project—thus avoiding lack of continuity.

As a company with a strong tradition in the area of basic sanitation, with a good technical and managerial base, Caesb managed to implement the system without great organizational difficulties, although it had to overcome some bad will initially—from a few technicians who viewed the system with distrust. Although in its initial phase the system originated from a policy decision made by the directors of the company, it gradually became assimilated into the technical group, and is now a solution that the whole company considers a pattern.

Caesb's experience demonstrates that it is possible to implement large-scale condominial systems, with limited finance and tight deadlines. However, you first need a well-established company structure and a management team that oversees all activities involved.

SYSTEM PERFORMANCE

The operation of the systems implanted up to now has indicated that there is no difference in maintenance frequency between the condominial and conventional systems. This can be interpreted as significantly favorable to the condominial system since, while the conventional system is operating in older areas of the city, which have good urban conditions and services for a higher-income population, the condominial system has been applied in expanding areas of the city, where normal urbanization is virtually non-existent, the population is low income and less used to this type of service. This being so, one would expect a larger number of interventions in the condominial system, which has not been the case.

Another positive aspect verified during maintenance of the condominial system is that the cost of interventions effected has been lower than that in the conventional system. This is because of the way the condominial system is constructed, where interventions are made more easily, and because of the maintenance technology itself. The experience obtained in Brasilia overturns the general view that condominial systems need more maintenance than conventional ones: rather, they need the same or less.

CONCLUSION

This work presents the experience gained in Brasilia using condominial sewerage systems on a large scale, with emphasis on the methodology developed. It tries to tackle all the key phases in the process of implementing the system, from the initial conception of the plans, including even their charging policy and maintenance, and presents the practical results obtained from systems that have already been operating for several years. These results proved that the condominial sewerage can be employed in a large scale program, as a pattern solution in a public company, allowing very low investments costs and normal operational performance. The achievement of these goals depends on a well-established company structure and a management team that oversees all activities involved, with a view that truly addresses the objectives of the system.

Learning Note

Community Based Sewer Systems in Indonesia: A Case Study in the City of Malang

Regional Water and Sanitation Group for East Asia and Pacific

UNDP-World Bank Water and Sanitation Program

Jakarta, March 1999

MALANG - BACKGROUND DATA

- Malang is located 80 km south of the provincial capital Surabaya, East Java.
- At an altitude of 400-650 m, the climate is markedly cooler than the coast; volcanoes to the north and northwest loom over the city, which is divided by several quite deep river valleys.
- 1997 population was about 790,000 (growth rate 2% p.a.); year 2000 population is projected at 820,000.
- Municipal area is approximately 11,000 ha: housing 4,721 ha; schools 500 ha; industry 165 ha and other 5,620 ha.
- Main employment: commerce (mainly small trade) about 30% and services for 40%, with industry (14%) playing a relatively minor role in the city's economy.
- The recent economic crisis has caused an influx of thousands of people, many of whom have found refuge in the poorer valleyside settlements, some of which are considered slums (*kumuh*) by locals; population growth rates in these localities is estimated at 5-8% p.a. by local NGOs.

Introduction

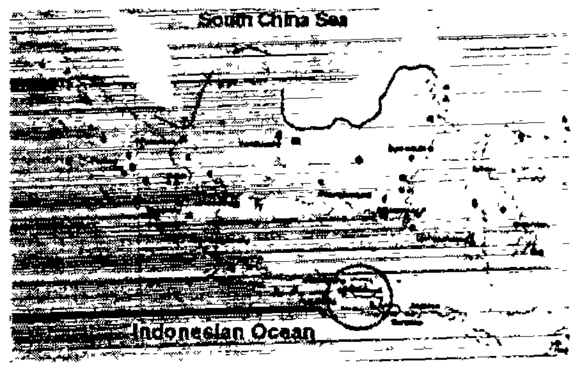
The urban population on Java currently amounts to some 43% of the total island population of 117 million.[1] Yet as a whole, Indonesia currently has the lowest rate of urban sewerage coverage in Asia. The environmental result is widespread contamination of surface and ground waters. Thus Indonesia has experienced repeated local epidemics of gastrointestinal infections and the highest incidence of typhoid in Asia. The economic losses attributable to inadequate sewerage are conservatively estimated at US$ 4.7 billion/annum (or 2.4% of 1997 GDP) - roughly equivalent to US$ 12/household/month (ADB 1999). As the simple benefit cost ratio for provision of adequate basic sewerage services is estimated at three to one, the case for financial support from government is straightforward and strong (ibid).

Some of the reasons for this situation are:

- GOI policy to-date assigns responsibility for the provision of sanitation facilities to families and others (World Bank 1993). This has inhibited the evolution of effective local government institutions for planning, implementing and operating sewer systems.
- The high cost and long lead times, disruption during construction, technical complexity and poor past performance of large centralized sewer systems.

Since about 1980 the proportion of the urban population in Indonesia served by sewer systems has stagnated, despite a steady increase in private on-site sanitation, now found in up to 80% of urban households. The partially treated or untreated effluent from these facilities typically flows into open drains or directly into water bodies. Proper disposal of human waste, either septage or sullage, is a rare exception. Given the scale of the problem, interest in neighborhood or community based sewer systems (CBSS) is increasing.[2] This case study summarizes one of the more successful examples in Indonesia.[3]

The main lessons that have emerged are familiar: A strong emphasis on the need for community mobilization and participation in all aspects of decision making, construction and operation of CBSS. As is clear from this study, there are strong and direct linkages between the depth of community participation and operational success.



Western Indonesia - showing the East Java region in which Malang is located.

The Role of Pak Agus Guntaro

In Malang, the initiative to develop a community sewerage system was taken in 1985 by one man, Pak Agus Guntaro, in his own community, Tlogomas, on the northeastern outskirts of the city. Since then he has been instrumental in encouraging other communities in Malang to establish their own systems. During the past several years these local efforts have begun to receive active external support - first from NGOs, then multilateral donors and the municipal government.

In Malang Pak Agus has played a catalytic and supporting role in almost all of the current systems. This has been especially important with regard to helping people in the community gain confidence that they are capable of meeting the technical, financial and organizational challenges.

In 1997 Pak Agus became a staff member of the Malang Municipal Sanitation Service (Dinas

Kebersihan) where he now leads a small team with a mandate to replicate the example of the CBSS in Tlogomas. During the past two years this team has played an active role assisting other communities in Malang establish their own CBSS. This has included assisting them with community organizing, accessing sources of external funding and negotiating permission to construct treatment facilities on government land. In contrast to the subsequent CBSS initiatives in Malang, Tlogomas was entirely funded by the community.

Case Study Setting - Malang, East Java

The geographical setting of Malang is representative of medium-sized cities located in the hillier parts of Java. The urban area is divided by fairly deep river valleys and most of the older parts of the city have been built on ridgelines. The newer parts of the city, especially the lower income areas, spread along the sides of river valleys where land is "available." In general, the riverside location makes disposal of waste - solid and liquid - physically easier than on the ridges, but not healthier or more environmentally responsible.[4]

Typical Riverside Low Income Community

Program History

The first CBSS in Malang was established in Tlogomas. Since then CBSS have been established in the five following communities: Watugong, Mergosono, Bareng, Samaan and Gadang. All these neighborhoods are densely populated urban settlements.

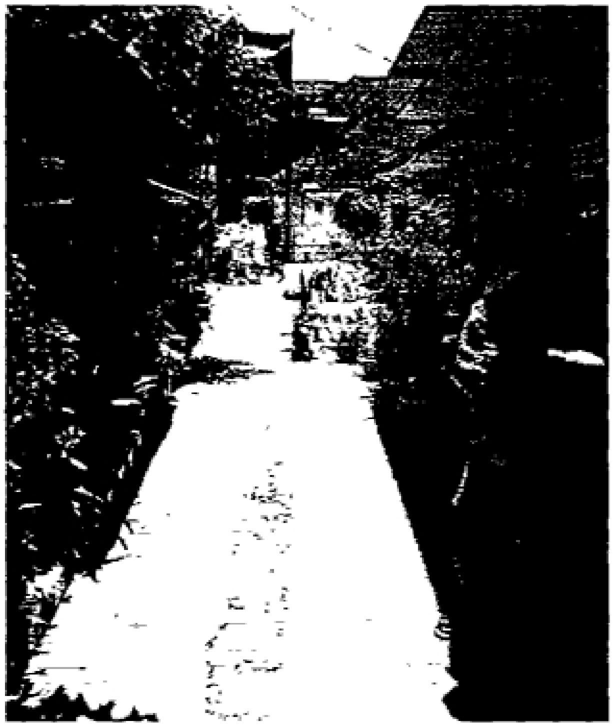
A localized diarrhea epidemic in part of Tlogomas in 1985, led to the death of five children from poor families. This was the catalyst for women in the community to start agitating for improvements in drainage and sanitation. Until that time small children still defecated in the open drains that bordered the laneways, making living conditions both unpleasant and unhygienic. Many families still used the river as their toilet. The openly expressed concern by the women led to a group of six families deciding to initiate community action to overcome the problem. Pak Agus, newly appointed to the position of neighborhood head, became the facilitator and leader of this group. He searched out information on sanitation systems from friends and colleagues in Malang. The solution chosen was to build a community sewerage system. The group of families began by pooling their own limited funds and then organizing with neighbors to collect more funds, acquire materials and begin construction of the system. In Tlogomas both men and women played an equal role in making plans, accumulating funds and constructing the system, but women were the initiators. Women who were concerned about open drains and unsanitary conditions also played a central role in initiating action in most of the other communities studied.

Over a period of more than a year Agus worked to convince other members of his neighborhood to contribute to the construction of the system. Space was available for the treatment facility on communal land adjacent to the graveyard and watercourse. Despite significant community support it took nearly two years of focused work before the system was operational. And although the six initiating households started using the system in 1987, it was almost 10 years before all members of the community were connected to the system.

Brantas River - multiple uses: bathing, washing and toileting

The other five systems studied within Malang have all been evolving since 1993, with most being constructed since 1997. With one exception (Gadang), these systems are located in the densely populated communities along the sides of several river valleys within Malang. Local population densities are in the range 200-400/ha. These are communities at the edge of poverty, and most of them have sections which can rightly be classified as slums. The neighborhoods are well ordered and kept clean by the community.

The pattern of settlement in these river valley neighborhoods is distinct from that found in the better off adjacent neighborhoods located on the flatter ridges. On these ridges the streets are broader, houses larger and more elaborate, and population densities much lower. Hence, the physical, technical, social and economic factors influencing establishment of CBSS differ widely between these two types of communities.



Tlogomas - Main pipeline laid in laneway.

The emerging pattern for establishing CBSS is that a community, often with outside stimulus, decides to take action and begins the lengthy process of accumulating funds, planning the technical aspects of the system and then, using community labor supported by craftsmen, constructs the system. Work begins with the treatment plant, progressively extending the main collection network and connecting household. The speed with which the system becomes operational depends greatly on the extent of community organization and motivation. The rate at which households connect depends on their willingness to pay for the connection and internal plumbing and equipment (which they may be able to do by installments or through a local revolving fund). Some houses simply do not have space available for building a WC, and the need for communal or shared toilet facilities is fairly common in the most densely populated areas. These factors are more important than availability of external financial and technical support.

Malang - Crowded laneway in a poorer neighborhood.

In addition to the community initiated systems, there are three larger systems now in the final stages of planning - these will service large portions of the kelurahan of Ciptomulyo, Mergosono and Jodipan. They are being financed under the second East Java Urban Development Project (EJUDP 2) loan from the World Bank. Although the technology is similar and only a little more complex than the community based systems, they are professionally designed and will be built by contractors. As a consequence, the per capita cost of these systems is considerably higher than the community based systems, although projected O&M costs per unit volume treated are similar. These loan-funded systems will be constructed using a mixture of contracted and community labor, and will be operated by the community; long term technical support for O&M needs are still being worked out.

The table below summarizes the locations and number of people served by the six CBSS studied in Malang, and those that will be served by the three larger systems soon to be constructed.

Kotamadya Malang - Small Scale Sewer Systems, Operating and Planned.

Kelurahan	Potential Service Area (H'holds)	No. H'holds Using	Approx. No. People	Population Density (pers/ha)
Community Initiated/Based Systems				
Tlogomas	67	67	585	64
Watugong	223	108	540	64
Mergosono	600	200	1,000	367
Samaan	60	20	100	243
Bareng	60	9	45	183
Gadang	95	0	0	78
Sub-Total	**1,105**	**404**	**2,020**	-
Planned World Bank Financed Systems				
Kelurahan	Potential Service Area (H'holds)	No. H'holds Registered	Approx. No. People	Population Density (pers/ha)
Cipto/Mergo*	3,200	3,249	16,245	178/367
Jodipan	2,700	1,854	9,270	284
Sub-Total	**5,900**	**5,103**	**25,515**	-
Grand Total	**7,005**	**5,507**	**27,535**	-

Percentage Coverage with Current and Planned Systems

	No. H'holds	Population
Malang Municipality	155,000	775,000
Percentage served	4%	4%

Notes: * Cipto/Mergo=Ciptomulyo/Mergosono. Population Density is in persons/ha for 1996 (BPS Malang 1998). From discussions with BPS Malang, population data is almost certainly an undercount by about 10%; there has also been a major influx of people over 1997/98. There are significant variations in population density within each kecamatan and kelurahan, and periurban locations such as Tlogomas and Watugong include substantial amounts of agricultural and unbuilt-up areas. These population density data should be regarded as a lower estimate of actual densities.

Financial and Technical Background

Financial

All of the communities studied accumulated funds from their members to pay for the public investments (main pipe network and treatment plant) and semi-public investments (household connections) - see Attachment 1 for details. The funds are managed by special committees set up in the local neighborhood, either in the immediate neighborhood (as in Tlogomas) or a grouping of adjacent neighborhoods (as in Mergosono). All of the communities, except Tlogomas, received funding from government and/or donors as a contribution towards payment for the initial public and semi-public elements of the systems. Construction was undertaken by a mixture of voluntary and paid labor.

In each community all the households connected to the system are required to pay a small monthly service charge, and most communities have engaged one or two local people who are paid an honorarium for maintaining the treatment plant. Community arrangements for funding major repairs and longer term maintenance are still being discussed.

Technical

All of the CBSS studied are based on a network of 100 mm (4") plastic collecting pipes laid beneath footpaths or below existing drains running along walkways through the communities - see Attachment 2 for details. Flow is entirely dependent on gravity. The treatment plant is located at the lowest point in the system, and discharges into the river or local watercourse. Treatment plants are constructed from concrete and plastered brick tanks and chambers, some of the facilities are covered with light sheet metal shutters.

The treatment process used in all locations is Anaerobic-Suspended Biomass, often referred to internationally as communal septic tanks. Locally this has come to be known as the "Tanki AG" (or "Sistem AG") - from the initials of Agus Guntaro, who popularized it in Malang.

Lessons Learned

These lessons relate to closely interlinked aspects of what is occurring with CBSS in Malang. With the exception of the CBSS in Tlogomas, all of these systems are in the early stages of evolution and there are a number of important challenges still to be met. On the other hand, Tlogomas is a clear illustration that it is possible for a community to finance, build and operate a CBSS that is self supporting, meets national effluent discharge standards and successfully operates for an extended period of time.

General Lessons

The three broad lessons from the Malang experience to-date with CBSS are:

- *There exists a significant "unrevealed" demand for sanitation extending beyond the household level in poorer and middle income neighborhoods. This is contrary to the conventional wisdom that the demand is low or nonexistent and that people will not pay for these services.*

Until a local example was available to demonstrate it was possible, people were unwilling to try something that they could not see operating. Once there was a practical demonstration in a local community (Tlogomas), other neighborhood groups were much more open to taking action by themselves. In Malang the example of Tlogomas has served to stimulate interest by other communities in the city. The efforts of a few people have been sufficient to spread the news that it is possible for communities to fund, organize, build and operate a system.

Five additional systems have been started or have become operational in the year or so since Pak Agus began acting as a "consultant" to other communities in Malang. The local government has provided Pak Agus with a position and basic income that has allowed him to work full time promoting the CBSS approach and, in a variety of ways (e.g., stimulant funding) helped encourage community based action. It is also clear that people are willing to pay O&M costs, but the amount and reliability of payment appears to be closely related to the degree of community participation in decision making.

- *The main reasons for this "unrevealed" demand are that many people in Indonesia do not know really know what 'sewers' are, nor are they fully aware of the benefits of sewers and that there are innovative, low cost ways to build them.*

The example of Tlogomas offered concrete proof that they could be built by the community. Until this system was available local people had no knowledge of what might be possible. Nor, because of the "big and expensive" mind set, had the government been active in informing people that there were low cost options available, let alone constructing demonstration systems.

Once local interest has been aroused, providing basic technical and organizational support appears to be the key to a community making the necessary commitment.

- *Sewerage does not have to be prohibitively expensive and community based systems can be built for per household costs that are comparable to the costs of individual "septic" tanks*

Capital and operating cost information currently available suggests that CBSS are cost competitive with individual septic tanks. Moreover, in the medium term (5-10 years) it is possible that operating costs for CBSS may be considerably lower than for individual septic tanks. In situations where households already have septic tanks, the total additional investment per household is roughly equivalent to the cost of three years of sludge removal service, i.e. Rp 150-300,000. Technical issues appear to be the most easily addressable, and existing systems can be modified quite simply and cheaply.

Specific Lessons

The remainder of this section expands on the general lessons summarized above under the following five headings: (i) organizational; (ii) social (iii) financial; (iv) technical and (v) environmental health. This discussion is supported by two annexes providing detailed financial and technical information on the CBSS studied in Malang. The concluding section identifies possible roles for external support to accelerate popularization of properly constructed and operated CBSS in Indonesia.

Organizational Issues

The general lessons summarized above suggest that the most important issues are political and institutional rather than financial or technical. Decision making authority should be located where consumer services and those responsible for O&M are located. Local (and national) government institutions need to make it easier for communities to take the initiative in establishing a CBSS. When they do, governments should be better prepared to meet the communities' expressed or revealed needs for technical, financial and/or organizational support.5

Finding effective means for channeling appropriate financial, technical and management support to communities is a critical issue. A need exists to combine community efforts with support from third parties, including the respective roles of NGOs, external support agencies (ESAs), the private sector and local government.

It is not at all obvious that local municipal governments need to or should be in a position to dominate organizational arrangements. In fact, it may be preferable for the municipal government to be one stakeholder among equals. It is also unrealistic to expect that local governments will be capable of delivering all of the needed support to communities, hence there is a need to identify other institutions which can fill this role effectively. The role of the local government should be to act as an umbrella organization for channeling broader public funds and technical backstopping, ensuring adherance to national standards and regulations. The obvious candidates as implementation partners are local and national NGOs (with the social expertise, and which have or can develop the necessary technical skills), the private sector and, to a lesser degree, local technological colleges and universities.

The main organizational lessons learned include the importance of:

- Linkages between communities, NGOs and the private sector which can provide social and technical assistance to move from initial commitment to planning and constructing a CBSS;
- Given current local government capabilities in Indonesia, the role of local government should be limited to serving as a channel for pubic sector financing and – in some circumstances – provision of limited technical support. The danger remains, however, that local governments are quite capable of unwittingly undermining local community initiatives;
- Local techncial skills can be fostered and quality improved by working with local artisans and contractors, who can play a pivotal role in constructing and maintaining CBSS.
- Limiting the scope for CBSS systems in one neighborhood (RW) to no less than 150 and no more than 300 households. (In some areas, for technical reasons, this may be too large and about 50 households would be a more appropriate size.); and
- Establishing or working through local city-level institutions that can provide consistent, appropriate longer term technical and organizational support to large scale popularization of CBSS.

Social Issues

The most positive learning from all the systems studied is that they clearly demonstrate adequate capacity by poor urban consumers in Indonesia to initiate, organize, design, finance, construct and operate their own sewer systems. In the prevailing socio-political climate in Indonesia this is a major accomplishment and a significant finding. As noted, the success of the systems appears to be directly related to the depth of community engagement. Despite this, it is also fairly clear that an "animator" is often necessary - in this case, Pak Agus - to get social processes moving. Nevertheless, all of these systems would have benefited if appropriate technical advisory services were available early in the process.

Specific lessons learned include the importance of:

- Strong links between the depth of community involvement in planning, financing and construction and the successful operation of the systems;
- Social stimulus in the opening stages of preparation, through early facilitation, outreach/extension programs and cross fertilization among communities; and
- Proceeding at communities' own "social pace," especially as regards the evolution of management structures, and financing operations and improvements.

Financial Issues

The system initiated by Pak Agus in Tlogomas was completely self-financed by the community. However, the four subsequent systems studied all received outside financial support in one way or another at different stages in their evolution. It is widely recognized that communities, even relatively wealthy ones, are not capable of wholly self-financing sewer systems if they are to begin operating within a fairly short time span and be technically effective.

A further challenge is in deciding on the most appropriate means for channeling financial support to communities, without tying them up in red tape and while preventing large losses to corruption. Without moderate but consistent financial support - for technical advice and in some cases construction costs - it is unlikely that technically successful CBSS will be widely adopted. The issue is how can external support be made to stimulate community based financing without negatively distorting community expectations or "ownership."

Thus the critical issues are:

- Estimating how much stimulus is required, while avoiding undermining local fund raising efforts;
- The institutional mechanisms for providing, managing and accounting for funds, so as to minimize corruption;
- Scaling the amount of per capita financial support to the economic status of the community and the real technical difficulties involved in establishing the system - e.g., proportionately more for poorer communities in flat areas; and
- The timing and type of support - e.g. direct cash/material subsidy or indirect via provision of technical support. For example:
    - Making available minor amounts of "stimulant" funds fairly soon after the community commits itself to establish a CBSS, and then directly assisting the community to develop a workable medium-term financial plan;
    - Consulting directly with the community on a flexible package of funding that includes a mixture of direct financial support and financing of community-directed technical support during design, construction and start-up;
    - Establishing revolving funds within a municipality, with responsibility for management located (probably) at kelurahan level (a system of matching grants is another option that might usefully be tested).

Technical Issues

There is a fundamental need for improved technical support for system design and operation, as only a few of the current systems are meeting even basic effluent discharge standards.

The currently established CBSS in Malang have basically been designed using "folk technology." Such technologies are based on a pre-scientific understanding and explanation of the biological processes occurring. Despite this, Tlogomas meets the standard and all of the systems roughly halve the pollutant levels in the influent stream, even though they fall short of meeting national technical standards for effluent quality established in Indonesia. In most of the existing CBSS the influent level of BOD (400-800 mg/l) indicates they are also used for processing kitchen and food manufacturing residues. Hence, treatment systems either need to be designed to deal with high BOD loadings or be used only for toilet waste.

Despite technical shortcomings, the physical basis (piping, house connections, treatment structures) for relatively inexpensive upgrading exists, where nothing at all existed previously. The systems are slowly but systematically being improved. As a result the same structures, sometimes with additional treatment tanks and filters, can be made more effective while keeping the technology suitable for local O&M.

The main technical lessons learned include the importance of:

- Early provision of low key, informal technical advice and planning support to communities that have made a commitment to construct a CBSS, possibly as part of a broader package of assistance;
- Provision of short term, hands-on technical training for people from communities (for people and contractors) who will be involved in constructing and operating the system (these should include cross-visits supported by follow-up and advanced training courses targeted specifically at community functions); and
- Development of technical standards and packages suited to the actual economic realities of low income communities (including practical design, construction, connection and operating guidelines).

Environmental Health Issues

The study revealed a widespread awareness in the specific communities studied about personal hygiene, and broad improvements in practices. Such an awareness is unusual in Indonesia.

It is likely that increased awareness is to a significant extent due to the participatory process inherent in the CBSS approach. Thus the establishment of CBSS provides an ideal opportunity for addressing issues of community awareness related to environmental health based on community responsibility. This is an area of activity where a working partnership between the community, NGOs and local government is possible and necessary.

The main environmental health lessons learned include:

- The need for municipal governments to mount sanitation promotion campaigns and field mobile assistance teams to work with local communities developing participatory approaches;
- The value of encouraging external support agencies to provide educational and technical materials to support such efforts;
- Complementing the above with similar campaigns in schools; and
- Establishing a community environmental management group (BPPL), which can later become part of a broader network for managing CBSS and organizing a wider range of activities for improving local environmental health (as demonstrated by the NGO CARE in Malang).

Possible Roles for External Support

The challenge for ESAs is to devise means of speeding up establishment of technically robust CBSS in suitable locations in urban Indonesia. This is based on the conviction that CBSS is a valid, if not the only, alternative to large-scale sewer systems for significant portions of urban Indonesia. The effluent from properly constructed and managed CBSS can meet national discharge standards (Class B). Where CBSS are operating properly, they are potentially a permanent alternative to large-scale sewer systems for much of Indonesia, and they could also evolved to form components of larger networks involving trunk sewers.

The clear immediate challenge is to identify appropriate means for flexibly delivering basic technical, organizational and financial capacity improvement to communities interested in establishing CBSS. For reasons already discussed, a country-wide effort relies primarily on suitable NGOs and private firms rather than government agencies.

Nevertheless, the involvement of NGOs and firms will almost certainly require funding from external sources, at least in the near term. In the medium-term it may be necessary to devise ways for providing institutional support for forming or strengthening private sector agencies to deliver technical backstopping to local communities for CBSS start-ups or expansions; perhaps under contract to local government. Financial support to communities needs to be carefully designed, so that it only subsidizes the public goods component of CBSS, e.g., main pipelines and treatment facilities. Financial support of this type could help accelerate establishment of CBSS, especially in poorer communities and those lacking favorable topographical conditions.

Thus, having NGOs and private firms work simultaneously with municipal sanitary services (or their equivalent) and local communities will probably still be required during the short to medium term. In addition to other types of ESA assistance discussed above, city-wide and multi-city projects could also be supported by:

- Seeking agreement/acceptance from the major GOI agencies involved (PU and Bangda) that CBSS is in principle an appropriate solution for community sewerage treatment;
- Contracting with national/international NGO(s) or private firms to establish small teams capable of providing roving organizational, technical and financial skills support to both local communities and municipal governments;
- Providing small "seed" loans/grants, possibly delivered via NGO(s), to communities to construct those parts of CBSS which have a clear public goods character, e.g., the treatment plant and main pipelines; and
- Providing concessional finance from MOF to municipal governments to initiate small rotating loans or grants, distributed to and controlled by keluruhan (sub-sub-districts).

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[1] The 1997 total population of Indonesia was about 199 million, of which some 73 million or 37% were urban dwellers (World Bank 1998).

[2] The complex range of social, economic and institutional issues related to the advantages and disadvantages of centralized and decentralized sanitation systems, and the advantages of "unbundling" sanitation services is fully explored and discussed in Wright (1997).

[3] Other examples of CBSS can be found in Yogyakarta and Bandung.

[4] The topography of cities like Malang is in sharp contrast to the (larger) urban areas located on the coastal plains, such as Jakarta, Semarang and Surabaya, were the landscape is flat and flood prone, and the physical problems of waste disposal are exacerbated by size, sprawl and very shallow slopes.

[5] The findings in Malang echo findings from the international comparison and assessment of best practice for provision of urban infrastructure services to low income communities (World Bank 1996).

Attachment 1

Case Study Results - Financial

These findings clearly reveal the willingness of even poorer urban communities to contribute to the costs of constructing and operating CBSS. Nevertheless, direct and indirect financial support will be necessary if the CBSS approach is to make a substantial and timely contribution to resolving the sanitation crisis in Indonesia.

System Investments

Information on the financial aspects of the five the six CBSS was collected through sample surveys of 10%-50% of the households connected to each CBSS. Information on the history and involvement of third (external) parties was collected through informal discussions in each community.

Several types of investments are required to establish a system: (i) *public* investments for the construction of the treatment plant and main pipe network; (ii) *semi-public* investments for the connection from the main pipe to individual households; and (iii) *private* investments for the construction of household WCs, etc. The chronology of system development and the sources of different *public* investments are summarized in the table below.

CBSS Chronology and Sources of Finance for Public Investments.

Location	Project Initiated	Began Operation	Total Investment	From Community	From Gov't	From Other Sources	From H'holds
Tlogomas	1985	1987	6,000,000	6,000,000	-	-	95,000 [4]
				100%	0%	0%	
Watugong	Mar 1997	Jul 1997	27,000,000	8,800,000	1,000,000	17,200,000	75,000
				32.6%	3.7%	63.7%	
Mergosono	Mar 1997	Jul 1997	18,500,000	16,000,000	2,500,000	-	100,000
				86.5%	13.5%	0%	
Bareng	Mar 1997	Aug 1997	4,295,000	2,045,000 [1]	2,250,000	-	50,000 [2]
				47.6%	52.4%	0%	
Samaan	Nov 1997	May 1998	6,100,000	600,000	5,500,000 [3]	-	20,000
				9.8%	90.2%	0%	

Notes: All amounts in IDR at time of construction 1 = In Bareng accumulated community savings was actually only Rp 450,000 and the remainder was prefinanced by one wealthy family; conditions attached this prefinancing were not clear, and as a result it has become a source of serious conflict in the community. 2 = In Bareng only Rp 22,000 has so far been collected from each household. 3 = In Samaan includes funds from the special government program called the "social safety net" (JPS). In other words, it was driven by this government project. 4 = In Tlogomas poorer households only had to contribute Rp 75,000, other households contributed more The last column is the amount each household had to contribute.

It should be noted that these are all costs at the time of construction. High inflation and the drastic devaluation of the IRD over 1998/99 have radically increased the local currency cost of construction materials, especially those with a large imported content. If similar systems were constructed in 1999 the amounts required for the *public* investment would be much greater in most cases: i.e. Tlogomas Rp 12.6 million, Watugong Rp 19.0 million, Mergosono Rp 9.8 million; Bareng Rp 6.4 million and Samaan Rp 9.1 million.

A substantial part of the *semi-public* investments necessary for household connections have been borne (in most systems) by individual households. However, in Tlogomas poorer households had to pay less than wealthier households, while in three other communities the public and semi-public investments were combined and part of the investment in household connections was met from external financial support. In two of the systems (Tlogomas and Watugong) there has been an increase in the cost for all new household connections - from Rp 75,000 to Rp 150,000 and Rp 95,000 respectively - clearly reflecting the community's understanding of the value of the existing investments.

Current System and Per Capita Public Investment Requirements.

Location	Total Public Investment Required		Population Served	Public Investment per Capita	
Location	IDR	US$	(actual)	IDR	US$
Tlogomas	12,614,000	1,417	585	21,562	2.42
Watugong	19,058,000	2,141	880	21,657	2.43
Mergosono	19,780,000	2,223	800	24,725	2.78
Bareng	6,428,000	722	145	44,331	4.98
Samaan	9,143,000	1,027	150	60,953	6.85

Notes: Calculation of Public Investment Required is based on current 1999 material prices and a participatory community approach using mainly voluntary labor. Population Served based on the current number of people connected, in some communities this is significantly higher than the normally assumed 5 persons/household, e.g in Tlogomas. The original contribution to Mergosono from CLEAN was used for a number of other community projects in addition to the CBSS, this figure is based on investments required only for CBSS at current prices In Bareng and Samaan the number of people connected is below design capacity, hence the apparent public investment required per capita is higher.

Typically, the initial *public* investment required to construct a CBSS was about US$ 3/capita, US$ 15 per family of five, or about Rp 135,000/family. The investment required depended on the following factors: (i) the number of households served per system, as up to a point it is cheaper the more households are connected; (ii) population density, as higher density allows more people/households to be covered with a similar length of main piping; and (iii) favorable slopes, as these reduce costs as smaller pipes can be used for the mains. However, the larger the system the greater the management challenges for (semi-) traditional types of organization.

In Indonesia, the RW (community group) of about 150-300 households is probably the optimal size from both the technical and organizational perspectives. Within this group (made up of a number of adjacent RT) there is a high degree of cohesiveness, solidarity and mutual social control, and this size of group is also large enough to be able to accumulate the capital necessary for public and semi-public investments.

Overall System Investments

The amount of semi-public investment required is probably best illustrated by the case of Tlogomas - the only community where all costs were borne locally - at current prices this amounted to some Rp 150,000 or about US$ 18/household. Thus, in Malang, total current investments required per household are about Rp 285,000 or US$ 33. Assuming that payment could be spread over 20 equal monthly payments - as appears to be the current pattern - this is equivalent to about Rp 14,000/month/household or about US$ 1.70; this does not include private investments in building a WC or bathroom. The comparative costs of building an individual septic tank are currently about Rp 300-400,000, and maintenance costs (sludge pumping) about Rp 50-100,000/year.

Community Contribution vs. Community Income

There has been much discussion in Indonesia concerning willingness-to-pay and the priority placed by a community on sanitation systems vis-à-vis other priorities. In general the conclusion has been that providing primary treatment sewer systems is a challenge beyond the abilities of the community. A closely related issue has been communities' ability-to-pay for 'expensive' sewer systems, especially in low income areas where it has been argued (or assumed) that they are not capable of financing even communal facilities. This has led to a situation where for long time it has been assumed that improved sanitation depends almost wholly on government investment. In reality the cost (per capita) of the system depends very largely on the feasible technology options, the technology chosen and the degree of self-reliance possible during construction; in general, costs will be higher per household for (smaller) piping systems constructed on flat or nearly flat land.

In Malang the most effectively operating system is the one that was built without any outside contributions - so clearly the community assigned it a high enough priority and, having done so, managed to accumulate the needed funds. In the table below the monthly family expenditure of all those connected to the systems is presented.

Monthly Family Expenditures of Households Connected to CBSS.

	Family Monthly Expenditure Range					
Location	<300,000	300,000 - 450,000	450,000 - 600,000	600,000 - 750,000	750,000 - 1,000,000	>1,000,000
Tlogomas	0%	10%	20%	20%	10%	40%
Watugong	0%	36%	27%	18%	9%	9%
Mergosono	29%	29%	15%	21%	0%	7%
Bareng	25%	25%	0%	0%	25%	25%
Samaan	13%	0%	50%	38%	0%	0%
Average	**13%**	**21%**	**23%**	**21%**	**6%**	**15%**

Notes: All amounts are in early 1999 IDR/month. Families with monthly expenditure below Rp 300,000 (2nd column) are classified as being below the current poverty line, while those in the Rp 300,000-450,000 range (3rd column) could easily slip into the lowest income group through illness or any number of other family misfortunes. At the time of writing (March 1999) the actual 'poverty line' is probably close to Rp 450,000/month/family. The survey enumerated all family expenditures using prepared schedules, i.e. here expenditures are a surrogate for family income. In Indonesia this is regarded as a much more reliable means of judging a family's economic situation than attempting to identify and quantify all sources of income. It is similar to the method used by BPS in National SocioEconomic Survey (SUSENAS).

Relative Size of Family Contributions to CBSS Investments.

Location	Contribution for Public Investment	Contribution for Semi-Public Investment	Total Community Contribution
Tlogomas	170,000 *	150,000	320,000
Watugong	75,000	95,000	170,000
Mergosono	100,000		100,000
Bareng	50,000		50,000
Samaan	20,000		20,000

Notes: All values in current IDR; i.e contributions in Tlogomas have been adjusted for inflation and price rises. Public Investments are those for the treatment plant and main pipe network, semi-public investments are those for household connections. In Mergosono, Bareng and Samaan public and semi-public investments were combined, and all three communities received substantial 'external' funding.

In Tlogomas (completely community financed) individual households contributed the equivalent of between 21% and 85% of one month's family income. In comparison, in Watugong, (33% financed by the community) family contributions amounted to 11% to 45% of monthly family income, and in Mergosono, (86% community financed), they contributed between 7% and 28% of monthly income.

Operations and Maintenance Costs

Information on contributions towards O&M costs were collected by interviews, however non-cash contributions to O&M (e.g. voluntary labor) were not included. In investigating this issue it was essential to clarify whether each group of users (community) had nominated an operator (*pengurus*), and if so what his main duties were, whether records were kept and the value of the periodic user contributions. This organizational information is a preliminary indication of the differences between the communities in how they deal with O&M costs and practices, and makes clear the fact that it takes some time for organizational arrangements to mature; the conflict in Bareng sharply illustrates the vulnerability of CBSS to unresolved local financial/political issues.

Based on this information, all families connected to CBSS in Malang spent significantly less than one percent of total monthly expenditures on O&M of sewerage, and an almost identical amount on solid waste services, compared to total expenditures of 2.5% to 4.5% on all utilities (water, electricity, solid waste and sewerage). This percentage was relatively higher for poorer families; in general, electricity accounted for three quarters of expenditures on utilities. Compared with findings of the ADB (1999) study, which found people paying or willing to pay 2-4% of their income for combined solid waste and sanitation services, O&M expenditure data from the current study are much lower. The reasons for this include the possibility that these systems are relatively inexpensive to operate as compared to the average costs of on/off-site sanitation in Indonesia and, with the exception of Tlogomas, these systemns are relatively new and major maintenance costs are yet to be encountered.

Attachment 2

Case Study Findings - Technical

These findings indicate that local people have not yet had an opportunity to learn about important biological processes and the role that good design and management plays in facilitating or hindering waste treatment. This illustrates the need for much improved technical support

Technical Performance

One of the first criteria used for assessing technical performance was the ratio of the *design capacity* to the *used capacity.* In all but one case (Tlogomas) the used capacity was only 23% to 87% of design capacity. The general effect of this was to lower the retention time available for biological processing. The number of people per household and the types of waste the systems process varied widely between the communities studied. Official population data of average family size can be misleading, as in three of the communities boarders (mainly students) added substantially to the number of people living in many houses. In most communities the systems are also used for gray waste (kitchen, bathroom and laundry) plus waste from food processing, laundry services and catering - this can greatly increases BOD and COD. Based on the findings from the surveys, an average of 80 liter/capita/day of wastewater production was used as a basis for further analysis.

People Served, Daily Treatment Volumes and System Capacities.

Location	No. of H'holds Connect	No. of People Served	Volume Treat/d (m3)	Design Cap'y (m3)	Used Cap'y (m3)	Present Retention Time (hrs)	Potential Retention Time (hrs)	Max Cap'y (H'holds)
Tlogomas	65	585	46.8	72	72	36.0	36.0	70 *
Watugong	104	880	70.4	33	23	7.8	11.3	50 #
Mergosono	160	800	64.0	42	24	8.9	15.8	80 #
Bareng	22	145	11.6	18	16	32.0	37.0	30 *
Samaan	30	150	12.0	59	13	26.4	117.6	98 *

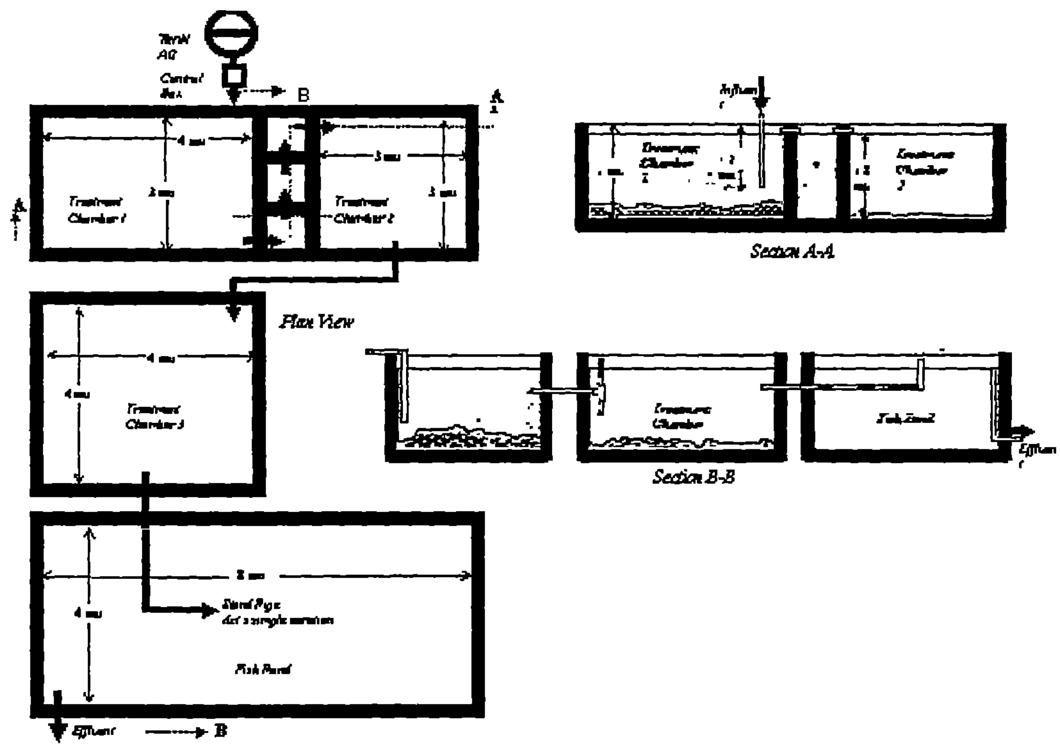
Notes: Volume to Treat/day is based on 80 l/cap/day times No. of People Served; the Design Capacity is calculated from measurements of the treatment chambers in each system; Present and Potential Retention Time are daily average times, actual times vary widely throughout each day. In the last column (Max. No. of Households Possible to Connect), * = possible to connect additional households and # = system already overloaded.

The CBSS, as the tables above and below show, were both "under" and "over" loaded. Both occurred as a result of misunderstandings by local people about the hydrological and biological principles underlying operation. They were under-loaded because the full design capacity was not usually used. As a result, the retention time was lower than it could or should be; for Malang the appropriate retention time is about 36 hours. Some of the systems were over-loaded, as volumes were too high to be processed to meet National Standards for the second lowest classification (Class C) effluent standard even if they were to be operated at full design capacity.[i]

Of the five systems studied only one system (Tlogomas) almost met the Class B (see below) effluent standards. Discharges from Watugong and Mergosono were higher than standard as the *used treatment* capacity was lower than the hydraulic capacity and organic loading, and it was higher than standard in Bareng and Samaan because these systems were not operated properly.

Treatment systems consist of the following main components: Grit chamber - a concrete cylinder with a wall/baffle in the middle (except in Mergosono) - to prevent solid material from entering the next processing chamber; Control Box; Treatment chambers 1and 2; Settling chambers (three small) - between chambers 1 and 2 - to reduce the amount of suspended solid entering chamber 2; Treatment chamber 3 and Fish pond - both only in Tlogomas.

Tlogomas CBSS: Plan and Cross-section of the Treatment System



CBSS Treatment Effectiveness: BOD, COD and TSS Levels and National Standards.

	BOD			COD			TSS		
Location	Influent (mg/l)	Effluent (mg/l)	% reduc'n	Influent (mg/l)	Effluent (mg/l)	% reduc'n	Influent (mg/l)	Effluent (mg/l)	% reduc'n
Tlogomas	202	60	70%	331	121	63%	58	23	60%
Watugong	300	220	27%	563	422	25%	250	149	40%
Mergosono	938	400	57%	1,447	965	33%	850	230	73%
Bareng	400	180	55%	984	351	64%	131	53	60%
Samaan	475	180	62%	884	382	57%	247	53	79%
Average	**463**	**208**	**55%**	**842**	**448**	**47%**	**307**	**102**	**67%**
National Water Discharge Standards (mg/l)									
Class B		50			100			200	
Class C		150			300			400	

Notes: BOD = Biological Oxygen Demand (5 day); COD = Chemical Oxygen Demand, TSS = Total Suspended Solids. pH and Turbidity were also determined; pH for both influent and effluent was consistently in the range 6-7.

Nevertheless, all of the systems individually achieve a significant reduction in pollution discharge. The pollution load originating from the community had been halved, despite the systems' current inability to meet national technical standards. One of the main reasons some of these systems have trouble meeting the standard is the high loading from disposal of kitchen and small-scale industrial food processing wastes. For example, in Mergosono this is probably responsible for 200-400 mg/l of the BOD load. In practice it is almost impossible to separate black and gray waster streams, as in most communities this would require re-plumbing almost all household and many public connections. As a result it is important that new systems are designed to cope with this additional loading and 'shocks' from sudden load increases; existing systems need to be retro-fitted to improve processing capacity.

Identified Problems and Proposed Solutions

What follows should *not* be read as a listing of "mistakes" but as a series of markers along the road of lessons learned, leading hopefully to future improvements.

Design Criteria. From a hydraulic point of view, the topography of the Malang municipal area is generally favorable, making it relatively easy (but not guaranteed) that the slopes of piping will be adequate. Major problems may arise in areas with shallower slopes where detailed measurements are needed. These problems can be addressed if small "CBSS technical teams" receive basic training in how to assist community groups and are equipped with simple instruments such as hand levels.

Design Standards. The differences between systems do not appear to be related in any systematic way to the number of people to be served, the location or land area available for the treatment plant. There is a need for simple, graphical design standards and construction guidelines, as the CBSS in Malang all have largely *ad hoc* designs that derive from the original system in Tlogomas.

Understanding Biological Treatment. The technical shortcomings noted above can be explained by lack of local knowledge about how a sewerage treatment plant operates. Without this technical understanding, people do not realize the impact of different dimensions and practices on operations - e.g. relative heights and volumes of treatment chambers. It is also clear that the biological processes involved are barely understood at all, making it even more difficult for people to judge the effect of design on performance.

Facilities for Maintenance. None of the CBSS studied were equipped with 'manholes' to allow clearance of blockages. Local people explained this had not led to any problems because the steep slopes allowed flushing through a few control boxes, usually located at junctions. Control box covers are made from concrete slabs, with no provision for lifting - this is another instance where practical advice would be valuable in future projects.

Quality of Materials Used. People are aware that lower quality materials reduce the durability of the system, but make a conscious choice between using affordable materials and having no project at all. Hence, the PVC piping used was of the lowest quality, the quality of the bricks was good but the reinforced concrete was poor quality. For control boxes and the grit chambers lower quality materials are acceptable, but for the treatment facility good quality materials and construction is required to ensure structural strength, proper operation and a long service life.

Maximum Service Capacity. Discussion with community leaders revealed that they did not have a clear idea of how many households could be served by the existing systems or how this number might be estimated. Usually the total number of households in the community was used as the service target, with the idea that "more connections is better" as this would increase income from the connection fee and monthly service fees. In three of the communities it is possible to connect more households, but in two the system is already overloaded (see table above). This is another instance where technical support would pay large dividends.

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[i] There are four classes (A, B, C and D) for water quality according to the Indonesian National Discharge Standards (*Baku Mutu Air Limbah*): 'B' standard water is suitable for disposal into water bodies that are processed for drinking water, while 'C' standard water is deemed suitable for fisheries and livestock watering. The most relevant standard in this instance is somewhere between Class B and C, as the current ambient level of pollution in the Brantas River at Malang is e.g., 50-100 mg/l BOD.

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Urban Sewer Planning in Developing Countries and "The Neighborhood Deal":

A Case Study of Semarang, Indonesia

by Dale Whittington
Jennifer Davis
Harry Miarsono
Richard Pollard

These Urban Environmental Sanitation Working Papers have not been formally published and this is an opportunity to share this information more widely to:

- stimulate discussion and to broaden thinking within the sector, and in particular, to encourage dialogue within and among our clients in developing countries; and
- build more awareness of the Program among UES clients.

Working Paper produced in December 1997

Urban Sewer Planning in Developing Countries and The Neighborhood Deal: A Case Study of Semarang, Indonesia

Human waste management is a burgeoning issue that is given insufficient attention by municipal governments in most cities in Indonesia, as well as higher level authorities. Current national policy is not clearly defined in this sector. However, it is evident that for most urban areas, on-site sanitation options such as septic tanks or pour-flush latrines, in large part financed by the families and communities being served, are preferred. Public investment in off-site services, ranging from communal septic tanks to conventional sewerage, must be weighed against the near-term benefits of investments in other infrastructure, such as housing and roads. Nonetheless, off-site alternatives with increased allocations of government resources will, in the foreseeable future, become a necessity. Tentative guidelines, currently loosely applied, are being established.[1] For example, The Ministry of Public Works recommends that sewerage systems be considered for areas with population densities higher than 300 people per hectare .

Investment in sewerage is generally considered to be expensive, and conventional approaches typically cost in the range of US$1,500 per household[2]. However, global experience suggests that a demand-focused, process-oriented approach that attempts to address the needs of all stakeholders can lead to significant cost savings and a balanced sharing of financial responsibility for both capital investment and operation and maintenance.

The World Bank has encouraged investment in human waste management in most of the integrated urban development projects it has supported. The Semarang-Surakarta Urban Development Project initially included financing for a pilot sewerage component that envisaged construction of a trunk sewer for part of the city, a treatment plant, and a feeder sewer network in one pilot sub-district[3]. Further dialogue between the Bank and the Municipal and Provincial Governments led to the conclusion that the pilot component must demonstrate a viable strategy for the gradual development of improved human waste management for the entire city. A fundamental step in this process was to assess current demand for improved sanitation among service consumers in order to help determine who would pay for what portions of sanitation services, and to prioritize areas of the city for different levels of service on the basis of demand.

The feasibility study described in this report was conducted to test a contingent valuation methodology for assessing consumer demand for sewer services. In essence, households and neighborhood groups were offered different theoretical pricing arrangements for house connections and feeder sewer networks, and the results analyzed to determine the deal preferred by each of the three sub-districts included in the study. While not a comprehensive assessment of willingness to pay for sanitation systems and services in Semarang, the data do provide some interesting and useful insights into consumer priorities for public and private investment in sanitation infrastructure. Although sanitation presents a more complicated mix of public and private responsibilities for households and communities than does drinking water supply, the study demonstrates that contingent valuation can be an effective approach for assessing demand for sanitation services.

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Richard Pollard, Jakarta, September, 1997

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1. Introduction

In most large cities in developing countries, only a small minority of households are connected to a sewer system. A tiny fraction of the wastewater from those households connected to sewers is treated effectively at primary or secondary wastewater treatment plants. The reality, then, is that cities in developing countries are awash in human sewage. Groundwater is contaminated from pit latrines and septic tanks; drainage ditches and canals are full of human waste; and surface water bodies such as lakes, streams, rivers, and nearby bays are heavily polluted.

Many observers assume that, because conventional technological solutions to these problems are well understood (e.g., water-sealed toilets, sewerage systems, and wastewater treatment plants), what is needed is simply more money. There is great uncertainty, however, regarding how to spend more on effective solutions to urban sanitation problems in developing countries. The first step toward a solution is not higher levels of externally-supplied funding, but rather a new policy framework that will ensure that available funds are used wisely.

Sanitation planning in developing countries has all the characteristics of what policy analysts have termed "wicked problems." There are several reasons why improving sanitation service poses such a complicated policy and planning problem. First, the costs of conventional water-borne sewerage solutions (e.g., on-site facilities such as water-sealed toilets, sewerage networks, and wastewater treatment) are expensive–on the order of US$25-35 per household per month (Lauria et al, 1995). This is equal to the total monthly income of many poor households in urban areas of some developing countries. Because the capital investments required for sewers and wastewater treatment facilities are so large, implementation of construction plans takes a long time and almost always involves cities in capital financing arrangements with higher-level government authorities and capital markets. Such long-term planning is problematic in low-income countries because poor households typically have high rates of time preference (McClelland et al, 1994).

Second, sanitation improvements result in public health benefits that have a public goods character: the benefits received by one individual do not diminish the benefits available to another. Standard public goods theory indicates that collective action is often required for the efficient provision of such goods in order to avoid free riding. But household sanitation improvements such as the installation of water-sealed toilets are not pure public goods; they also yield important private benefits, including convenience, time savings, and aesthetics. If housing markets are functioning reasonably well, the value of such improvements will be capitalized into housing and rental values. Households respond to these market prices and often sort themselves into neighborhoods by preferences for environmental quality, including neighborhood sanitation.

A third challenge to effective sanitation planning is the lack of public awareness of the benefits of sanitation services. Despite the fact that public health benefits ensue from collective solutions to urban sanitation problems, the public may not fully understand or perceive the magnitude of these benefits. In this sense, sanitation improvements resemble what economists term "merit goods," and social marketing and political leadership may be required to implement a socially optimal investment program. This line of argument, however, has often led public health specialists, planners, and engineers to rely solely on their expert opinion and to ignore the presumably uninformed wishes of households. One manifestation of this attitude is the response of water and sanitation engineers to the problem of low household connection rates to new sewer lines: "We'll make them connect!" Such professional arrogance has resulted in many spectacular sanitation planning failures.

Fourth, planners attempting to increase user fees in order to finance sanitation improvements often face a dilemma. Poor households are unable and unwilling to pay for sewer connections or wastewater treatment, while many richer households have already invested in individual solutions to their immediate problems. Thus it is likely that neither group will be inclined to participate in a collective agreement to improve public health conditions. Many poor households may not even have water-sealed toilets or effective on-site sanitation systems (such as VIP latrines). Quite reasonably, such households are generally unwilling to address community-wide problems until they have met their immediate household needs and have obtained the private benefits associated with improved household sanitation. There is less justification for the public sector to subsidize private housing improvements such as the construction of water-sealed toilets, yet without such investments neighborhood and city-wide plans must wait.

Fifth, sewer network design, construction, and operation are subject to a variety of economies of scale. Design engineers thus prefer to lay sewer pipe throughout a city and hope that households and businesses will connect. This approach requires that care must be taken to estimate demand for connections, something that is rarely done. If connection rates are low, this has several implications. First, public health and environmental objectives may not be fully achieved. Second, revenues will be lower than expected. Third, the network design task itself will become much more complicated in terms of sizing and location of interceptor and trunk sewers. A conventional sewer system may not function properly because of insufficient flows.

Finally, large amounts of money are at stake in the way water and sanitation projects are now constructed and financed. A new policy framework for sewer planning will likely threaten established financial relationships and will meet strenuous opposition from some stakeholders in the current system (Lovei and Whittington, 1993).

Despite these formidable challenges, policy analysts, planners, and government officials have become increasingly aware of the need for a new policy and planning framework in confronting the urban sanitation planning and implementation problem in developing countries. In this paper we argue that this new planning paradigm requires that neighborhood organizations and households be involved in an active partnership with government, donors, and technical staff. The problem is simply too complex to be left to planners and engineers working in government agencies, or to the consulting engineers that work for them. The essence of our argument is that government officials and technical staff must re-orient their thinking toward a new scale; rather than attempting to find an "optimal solution" to a city's sanitation problem, they should focus on structuring what we term the "neighborhood deal." This reorientation requires that government officials study household and neighborhood demand for improved water and sanitation services in order to design a "deal" that municipal and higher-level governments can afford, that is technically feasible, that is attractive to households, and that has public health and environmental benefits. Pricing sanitation services involves finding a set of prices (e.g., assessment fees, monthly tariffs, and connection charges) to be offered in the neighborhood deal. A sewer network designed under this approach will evolve over time in response to the incentives that government has incorporated in the neighborhood deal. If the incentives are well designed, then both the government and city residents should be satisfied with the dynamic evolution of the sanitation network. If not, then the deal may be modified as experience is gained.

There are two principal advantages of thinking about the sewer planning problem as a deal between neighborhoods, households, and government. First, sewers will be built where people actually want them, resulting in high connection rates and thus in substantial public health benefits. Second, with relatively high connection rates among neighborhoods participating in the deal, increased revenues will be available for the government to finance its part of the deal in other neighborhoods. A faster expansion of the sewer network will occur than if some neighborhoods received a disproportionate share of available subsidies. On the other hand, disadvantages of this deal making approach to sanitation planning include the complexity of network design for interceptor and trunk sewers and the slower progress in improving surface water quality.

This partnership between neighborhoods and government will not, however, be easy to achieve. It will require that planners and engineers relinquish some of the responsibilities and privileges they typically assume for shaping and designing urban sanitation policy. They will also have to consider households as their clients, not merely passive beneficiaries of a sewer project. Considerable time and effort will have to be spent working with local communities and neighborhoods before construction can begin. Moreover, the agencies responsible for water and sewer planning will need new staff with very different skills than the individuals they currently employ, or they will have to hire private consulting firms to provide them with such services.

In the next section of this paper we discuss the components of the "neighborhood deal." In Sections 3-9 we present a case study of the sanitation situation in Semarang, Indonesia, that develops our concept of a partnership between neighborhoods and city government in more detail. Section 10 summarizes our findings and conclusions. Our vision of a community-oriented sanitation planning process is contrasted with current investment strategies for expanding or initiating the construction of urban sewer networks in developing countries in Appendix A.

2. A New Sanitation Planning Approach: The Neighborhood Deal

It is our contention that the exclusion of neighborhood organizations and households from active participation in the planning process lies at the heart of the current sanitation planning crisis in many cities in developing countries. To appreciate why this is so, it is necessary to consider (1) what information planners and municipal governments need before committing to lay sewer pipe in a neighborhood and (2) what information households need before deciding whether they want a connection to a sewer line. Sound sewer planning requires that planners know both the number of households that will connect if sewer lines are installed, as well as the costs of sewering a particular neighborhood, including the implications for the entire sewerage network.

If it can be assumed that all households in a particular neighborhood will freely connect or can be forced to connect to new sewer lines, then this part of the planning problem is simple. If this cannot be safely assumed, as is typically the case, then the agency or authority responsible for the sewerage system needs assurance that, if sewer pipe is laid in a neighborhood, households will pay a predetermined amount for this infrastructure improvement. Simply put, a fiscally responsible authority cannot bear the financial risk of installing such expensive infrastructure without some form of payment guarantee. From the agency's financial perspective, each household in the neighborhood should be required to pay some share of the sewer network installation costs–whether or not that household obtains a connection–because the value of its property increases simply by having the option to connect in the future.

In practice, there are two principal means by which an agency could receive such assurance. First, individual households could sign a legally binding agreement with the agency which obligated them to pay a specified amount for the installation of the sewer lines. Under this approach, however, transaction costs for the agency are very high. Although 100% of households would not necessarily need to agree to participate, a minority of households could hold out, refusing to sign the contract with the agency, and delay the project for others. Moreover, once the lines were installed, the agency would have the difficult task of enforcing numerous contracts with individual households.

Second, the agency could require a financial commitment from the neighborhood as a collective unit before installing the sewer lines. A neighborhood organization would "assess" (i.e., tax) each household a certain fee for the installation of the sewer pipes in the neighborhood. Either the neighborhood organization or the agency could determine the amount of the assessment for each household. Such an assessment could take the form of an increase or surcharge on local property taxes or on local community improvement taxes. The key point is that the neighborhood as a collective unit would be required to make a decision about whether or not to have sewer lines installed. If a neighborhood decided to proceed with the installation, then every household would have to pay–even those against the plan.

The neighborhood organization would be responsible for financial transactions with the agency and for enforcing its collective decision on its members. This approach has the important advantages of (1) substantially reducing transaction costs to the agency, and (2) leaving the responsibility for a collective decision at the lowest possible administrative and political level, thus increasing the probability that the decision is responsive to local needs and desires.

Regardless of which of these two approaches is used to arrange for household financing of the neighborhood sewer network installation, there is still a household decision about whether or not to connect to the new sewer line. Clearly the collective, neighborhood-level decision regarding the installation of sewer lines and the household-level decision regarding a private sewer connection are interdependent. If a household does not want to connect to the sewer line, it may not want to pay for its neighborhood to have sewer lines installed. Then again, it may. By having sewer lines installed in the neighborhood, a household receives two benefits even if it does not know whether it will connect. First, it purchases the option to connect at some time in the future; this option will increase the value of its property whether or not it chooses to connect. Second, other households will likely connect, thus improving environmental quality in the neighborhood.

It is, however, certainly true that a household would need to know the costs of connecting to and using the sewerage system before it made a decision about whether or not it wanted its neighborhood to have sewer lines installed. In fact, there are many costs a household must consider when deciding whether or not its neighborhood should have sewer lines installed and whether it should connect to a sewer line if one were installed. First, it must consider the amount of, and financial arrangements available for, the assessment fee for the sewer line installation. Second, a connection fee must typically be paid to the water and sanitation authority by each household wanting to connect.

[4] Neighborhood organizations could, however, agree to make special arrangements for the poor and other special cases.

Third, additional plumbing costs are associated with actually connecting the water-sealed toilet (and perhaps household "gray water" discharges) to the sewer pipe. The latter costs are likely to vary significantly from household to household. Fourth, if a household does not already have a water-sealed toilet, it must incur the costs of installing one. Finally, households with a sewer connection must typically pay a monthly tariff. For those who already have a metered private water connection, this tariff may be a surcharge on a monthly water bill. For those without service, the monthly charge may simply be a fixed fee.

The different costs and prices that the household faces, along with the financial arrangements for paying them, can be influenced by policies of the municipal government and the water and sanitation authority. We refer to the bundle of all such policies as the "neighborhood deal" because it is useful to consider how the whole package of government policies appears to the neighborhood and to the household. There are thus many alternative deal structures" that the agency(ies) responsible for sewerage could offer neighborhoods and households. Each must somehow specify, however, the relationship between the collective decision necessary at the neighborhood level and the individual connection decision to be made by households.

In this context, it is perhaps easier to understand why investment strategies that exclude neighborhoods and households from the sanitation planning process have had such a high rate of failure. First, such approaches preclude neighborhood organizations and households from providing the water and sanitation agency with essential feedback about household demand for infrastructure improvements before sewer lines are installed and investment mistakes are made. Second, current investment strategies do not ask neighborhood organizations to bear the transactions costs associated with achieving collective agreements among households, and it has proven too difficult and expensive for government to shoulder this responsibility. Third, existing investment strategies utilize relatively simplistic "deal structures" without any empirical information about what households and neighborhoods actually prefer. In other words, government deals are frequently offered without any consultation or negotiations with neighborhoods or households. It is hardly surprising, then, that such deals are commonly rejected.[5]

3. Operationalizing The Neighborhood Deal Approach In Semarang, Indonesia

3.1 Introduction and historical perspective

We recently explored the potential for introducing this new sanitation planning approach in the rapidly industrializing Republic of Indonesia. Despite strong economic growth and urbanization, Indonesia remains under-served with sanitation facilities in both urban and rural areas.[6] Fewer than one million of Indonesias 190 million citizens have access to sewer service nationwide.

Private investment in on-site sanitation systems, primarily in septic tanks/leaching pits, has been substantial. In Jakarta alone there are an estimated 927,000 septic tanks, the vast majority of which have been privately financed and constructed. These systems may be effective in removing human waste from the immediate household environment, but little progress has been made in improving neighborhood sanitation conditions. Moreover, because such on-site systems are frequently poorly designed, constructed or maintained, they often contribute to human pathogen and BOD loadings in surface and groundwater.

The current policy of the Government of Indonesia (GOI) is that sanitation is a household responsibility. At same time, recognition of the need for public intervention is increasing; the GOI is aware that on-site systems are increasingly inappropriate in high density communities. Pilot sewerage investments have been included (for a limited number of cities) in the most recent Five Year Development Plan. There is also growing awareness that a revised strategy is required for addressing urban sanitation, but as yet no consensus exists regarding an overall approach, including financing strategies or technology selection. The prevailing view is that (1) consumer demand for off-site sanitation will very low, (2) the technology options will likely be very expensive, and (3) capital costs will need to be borne largely by central government. Hence, the requirement for large subsidies is implicit in the pilot sewerage schemes planned thus far.

None of the strategies for providing off-site sanitation service proposed to date has considered alternative approaches to achieving residential coverage, especially in low-income areas. Nor has a "strategic sanitation planning" approach been proposed that is demand-responsive, that presents a range of technology options, and that develops an institutional and financial framework allowing for costs and responsibilities to be distributed between beneficiaries, local governments and provincial/central government. Our work in the city of Semarang represents one effort to assess the feasibility of such a demand-driven planning approach.

3.2 Study site

The city of Semarang is the provincial capital of Central Java (see Figure 1) and is located approximately 540 kilometers east of Indonesia's capital, Jakarta. More than 1.3 million residents make Semarang Indonesia's fifth largest city (US Central Intelligence Agency, 1995), and population density in the city varies between 35 and 200 persons per km.[2] Semarang continues to grow at a rate of approximately 2% each year.

Semarang is a coastal city, facing the Java Sea to the north. Annual rainfall averages 2,100 millimeters. The region around Semarang has several teak forests and rubber plantations; these commodities, along with shellfish, coffee,

[5] The neighborhood deal may also be rejected because households may not understand how the technology of sewer pipes and waste water treatment works, nor the public health benefits likely to ensue. This may require that government initiate a proactive education and social marketing program to provide households such information.

[6] According to a recent WHO assessment, Indonesia had the lowest percentage in Asia of urban households with adequate sanitation (40%, compared to 84% in Thailand and 98% in the Philippines)

hardware, chemicals, and textiles comprise the principal products of the city. In addition, Semarang's port facilities make it an important transportation and shipping center. The city's economy, like that of Indonesia, is growing rapidly (averaging 7% annually during the period 1984-1994). Per capita gross domestic regional product for 1993 was estimated as US$560. Prices for most goods and services in Semarang are now close to international levels (Table 1).

Table 1: Average prices of goods/services in Semarang (July 1995)

Item	Average cost (Rp.)	Average cost (US$)[7]
1 kilogram rice	920	0.41
1 liter cooking oil	1,700	0.76
1 kilogram fish	6,200	2.76
McDonald's Big Mac	4,000	1.78
1 liter gasoline	700	0.31
One-way bus fare (local)	250	0.11
Cross-town taxi fare	13,000	5.78
Cigarettes (12)	1,000	0.44

Indonesia is divided into 27 provinces, each of which is further organized into six operational levels of government: provincial, district/municipal, sub-district, village, community, and neighborhood (see Table 2). As the capital of the Central Java Province, Semarang plays an important role in each of these government levels. The Provincial Development Planning Board (or Bappeda) oversees infrastructure development projects such as water supply and sanitation programs and is located here.

Within Semarang, communities are organized on several different levels. Between 10 and 120 households comprise an "RT" (Rukun Tetangga, or neighborhood association) which is headed by an unpaid, elected Chairman. Roughly 10 RTs are grouped into each RW (Rukun Warga, or community association). RWs, in turn, are grouped into kelurahans, headed by appointed lurahs; there are roughly 20 kelurahans in each kecamatan.

7 During July 1995, US$1 =2250 Rp.

Table 2: Organization of local government in Indonesia

'Government level	Head	Composition	Agencies with influence over development projects
Provincial	Assistant governor	Indonesia=27 provinces; 1 province=10-15 districts	Central government department offices; Provincial Development Planning Board (Bappeda); Development Bureau; Bureau of Finance
District	District head	1 district=5-10 kecamatans	Central government representative offices; Provincial Technical Offices; District Development Planning Board; Development Bureau; Bureau of Finance
Sub-district (Kecamatan)	Sub-district head (Camat)	1 kecamatan≅20 kelurahans	Sub-district Development Coordinating Unit; Sub-district Technical Offices
Village (Kelurahan)	Village head (Lurah)	1 kelurahan≅20 RWs	None
Community (RW)	RW Chairman	1 RW≅10 RTs	None
Neighborhood (RT).	RT Chairman	1 RT=10-120 households	None

4. Field Work

The objectives of this study were to begin to assist the Government of Indonesia and the World Banks East Asian Infrastructure Division responsible for Indonesia (EA3IN) in thinking strategically about new sewer and wastewater treatment investments in Semarang. The work of this mission was designated as Phase I of a two-phase project. The purpose of this two and one-half week mission was essentially reconnaissance. Our terms of reference included the following tasks:

1. To determine whether it was possible to implement a large-scale contingent valuation (willingness-to-pay) survey in Semarang to estimate household demand for improved services;
2. To determine whether it was feasible to use local enumerators and computer data entry and management resources;
3. To develop and pretest a household questionnaire; and
4. To determine whether and how a rigorous household sampling protocol could be implemented.

' Adapted from Nour, M. (1995). Indonesia. Urban Upgrading Project, SSUDP loan 3749-IND, Bandarhargo (Semarang) and Mojosong (Surakarta), Participatory and institutional aspects. Report to the World Bank, EA3IN.

Due to a series of fortuitous events, we were able to accomplish more than anticipated during this Phase I mission.

As a first step, we needed to gain an understanding of current water supply and sanitation practices in selected neighborhoods of Semarang and to assess residents' demand for improved water supply and sanitation services. Over a period of two and one-half weeks in July-August, 1995, we conducted both a household survey and a series of participatory community meetings in Semarang. As noted, these data collection efforts were designed and executed as pretests for a larger, more comprehensive study to be carried out in the future.

4.1 Sampling and training of enumerators and community organizers

Time and resource constraints precluded our drawing a rigorous random sample of Semarang households for the study. Instead, three kelurahans were selected purposively, with the intent of representing the range of residents' existing water supply and sanitation services and socioeconomic characteristics. The kelurahan Bugangan (see Figure 2) is a low-lying area near the coast; many residents of Bugangan rent their homes and do not currently have a private water connection. One of the two open canals that channel waste from the city to the ocean forms one of the boundaries of the kelurahan. The kelurahan Sekayu is located in a relatively affluent downtown district with a mix of high density, low- and middle-income housing and some business/office areas. Sekayu has been under consideration as the pilot area for planned improvements to the water supply and sanitation system under a World Bank-financed urban renewal and sanitation upgrading project. Dadapsari is a middle- to low-income kelurahan in the eastern part of Semarang.

A total of forty-two RTs–fourteen in each kelurahan–were selected for the study. [9] In each kelurahan, nine RTs were randomly assigned for inclusion in the household survey, and five for participatory community meetings. Household interviews were conducted by fifteen college-educated enumerators from Semarang (6 women and 9 men) over a six-day period. Half of the enumerators were students, and the rest were staff from the water supply utility, PDAM, the public works department, and Bappeda. Each community meeting was facilitated by one of three pairs of college-educated community organizers.

Intensive enumerator and community organizer training was carried out over a six-day period. This training was especially important to ensure that our study objectives and methodology were well understood. Regional and local governments in Indonesia often use household surveys and community meetings not to elicit information about attitudes and preferences from citizens, but to educate people toward a particular point of view. We thus used lectures, role plays, and practice presentations to ensure that enumerators and community organizers understood their responsibility to provide and gather information in an objective, professional manner.

4.2 Data collection techniques

Twenty different versions of a household questionnaire were developed over a one-week period of intensive pre-testing and revision. The four sections of each version were designed to collect information about respondents' existing water supply and sanitation situation; priorities and perceptions; willingness to pay for improved water supply and sanitation; and socioeconomic characteristics. [10] The survey was written and administered in Bahasa Indonesia, the most widely used language in Semarang.

Each questionnaire was administered to a head of household (and occasionally to both heads of household). Interviews lasted between 30 and 70 minutes and were conducted in respondents homes. A total of 319 questionnaires were completed.

[9] The sample design for the study is presented in Appendix C.

[10] A copy of one version of the household questionnaire is presented in Appendix B

A series of fifteen participatory community meetings was also convened during the study period. As with the household survey, these meetings were designed to learn how individuals in these neighborhoods perceive their existing water and sanitation situation and how they feel about possible improvements. Each meeting was convened by an RT chairman and facilitated by a two-person team of community organizers. The meetings lasted one to two hours, and attendance varied from 10 to 31 people.

5. Socioeconomic profile of sample

Of the 319 respondents interviewed in the household survey, 125 (39%) are female and 194 (61%) male.[11] Among survey respondents, the average number of persons per household is 5.7, and 15% of the sample households are headed by females. The mean age of respondents is 49 years. Five percent of respondents have earned a college degree, 41% have graduated from high school, and 12% have not completed primary school. Three quarters of the respondents are Moslems, while another 21% are Christians and 4% are Buddhists.

Three quarters of the survey respondents and 55% of community meeting participants own their homes; almost 90% of those interviewed live in single-family dwellings. Among survey respondents, houses have an average of 4.6 rooms, and all receive electric service. The average household monthly electric bill is 15,500 rupiah (US$7.20). When asked to estimate the current market value of their homes, survey respondents provided values ranging from 1,000,000 to 100,000,000 Rp., with a mean of roughly 26,500,000 rupiah (US$12,320). The average market rental prices for homes is 32,245 rupiah (US$15.35)[12].

Survey respondents reported household monthly incomes ranging between 3,000 and 2,000,000 Rp. with a mean of 305,421 rupiah (US$142). More than 80% of households interviewed own a television, and 22% have a telephone. Motorcycles are a popular mode of transportation in Semarang; almost one half of the respondents own a motorcycle (10% own an automobile).

6. Existing water supply

A piped water system operated by the public water supply utility, PDAM (Perusahaan Daerah Air Minum) delivers water to roughly 25% of Semarang households. Among the 319 persons interviewed in the household survey, 88 (28%)reported having a working private water connection in their homes.[13] Virtually all of these respondents also have working water meters at their homes. Average monthly water bills range from 5,000 to 55,000 Rp., with an overall mean of 14,139 Rp. (US$6.28). Only one respondent reported selling water to neighbors. Almost all respondents with connections use the water for drinking and cooking (see Figure 3); every household reported boiling its water prior to consuming or cooking with it. In general, respondents rated the quality of water from their connections highly (see Table 3). Only 8% felt it had a bad odor and 1% thought it appeared dark or dirty. Nineteen percent reported a strong chlorine taste in their water, while 78% considered it "normal" or "fine."

[11] A significantly higher proportion (79%) of males participated in the community meetings (men frequently represent their households in community events in Semarang). The format of the community meetings was not conducive to the collection of many additional socioeconomic data

[12] This average includes only those respondents living in non-subsidized housing. More than one third of the respondents who rent their homes, however, live in subsidized rental units and pay less than 5000 Rp (US$2.40) per month in rent.

[13] Twenty-one percent of community meeting participants reported having a household water connection.

Table 3: Perceptions of water quality from private connections

Percent of respondents with connection who give good rating to wates...	Odor	Color	Taste
	89%	96%	78%
Percent of respondents who boil water from connection prior to consuming		100%	

Approximately half of survey respondents' households have a private well; another 20% of respondents reported collecting water at least occasionally from a public well in their neighborhood. Half of these pay an average charge of 150 rupiah (US$.07) per 50-liter pikul, and the other half pay an average monthly fee of 9,500 rupiah (US$4.22) for unlimited access to the public well. Well water is used primarily for bathing and washing; only 3% of those using private wells and 14% of those using public wells utilize the water they fetch for drinking or cooking. Although respondents using well water generally consider its odor to be acceptable, 22% feel its taste is "salty" and 25% that it appears "dark" or "dirty."

Reliance on vended water varies dramatically among the three kelurahans. Eighty-one percent of respondents in the Bugangan district reported purchasing vended water at least occasionally, whereas only 12% of the Sekayu respondents use vended water. Among all respondents, 11% reported obtaining "all or almost all" of the water their households use from vendors. These households purchase, on average, between four and five jerricans daily. With an average price for a jerrican (20 liters) of water of 295 rupiah (US$.13), these households are thus spending roughly US$18 for vended water each month.

Vended water is primarily used for drinking or cooking, although 10% of respondents also reported using water from vendors to wash clothes and dishes and to bathe. As with well water, vended water was reported to have a salty taste by 20% of respondents who use it. Few respondents, however, said that vended water has a poor odor or appearance.

7. Existing sanitation service

Semarang currently has no sanitary sewer system, and wastewater overflows in open combined sewers/storm drains to the Java Sea without treatment. The majority of the city's households are served by private water-sealed toilets (see Figure 5); approximately three quarters (73%) of survey respondents reported having a toilet for the exclusive use of their household members. The waste from the vast majority of household toilets is deposited into septic tanks without septic fields. Fifty-eight percent of respondents with a private toilet and septic tank reported having emptied the tank at least once; 15% have replaced their septic tank or installed an additional tank (Figure 6).

Public latrines are the primary form of sanitation service for almost all other respondents, primarily residents of the relatively lower income kelurahan Dadapsari. Approximately half of users are required to pay a contribution fee to visit the public latrine. A fixed monthly fee is the most common payment arrangement, with an average fee of 1,040 rupiah (US$.46). Another 40% of respondents who use public latrines regularly reported paying a charge per visit; the average price was 85 rupiah (US$.04).

8. Priorities And Perceptions

Respondents in the household survey were provided a list of social and environmental priorities facing Semarang and asked to select the issue they felt was the most important to resolve. As shown in Table 4, one third of all respondents were concerned foremost about flood water drainage. Almost half of those living in the Bugangan kelurahan–a low-lying area near the

Java Sea–chose the improvement of flood water drainage as the most important issue to resolve. Those in the center city kelurahan of Sekayu were more concerned about providing a safe and reliable water supply to residents. Overall, the improvement of sanitation was perceived as a top priority by only eleven percent of respondents.

Table 4: Respondents' social and environmental priorities

	Percent of respondents ranking as top priority in...			
	Bugangan	**Dadapsari**	**Sekayu**	**Overall**
Drainage of flood waters	45	39	17	33
Safe, adequate water supply	20	29	30	27
Improved sanitation services	12	10	11	11
Solid waste collection	13	11	8	10
Improved hospitals and clinics	5	3	16	8
Quality of education and schools	3	2	12	6
Improved road conditions	2	6	6	5
TOTAL	100	100	100	100

Survey respondents were also asked about their satisfaction with the current environmental conditions in their RT. Specifically, they were asked whether their household could smell both the large, combined storm sewers/drains, as well as the smaller neighborhood drains, from their homes, and whether the odors were noisome. As shown in Table 5, approximately one quarter of respondents reported smelling the large canals from inside their homes, and one half were aware of the odors emanating from their neighborhood drains. More than 80% of those who said that they could smell these odors also said that they were "bothersome." At the same time, when asked to rate their satisfaction with existing sanitary and environmental conditions in their RT, only 10% classified themselves as "unsatisfied." These results reinforce the findings in Table 4 indicating that sanitation is not viewed as a high priority by many residents of the kelurahans we studied.

Table 5: Survey respondents' perceptions of environmental conditions

	Bugangan	**Dadapsari**	**Sekayu**	**Total sample**
Can smell large canals	9%	48%	7%	23%
(If yes), is bothered by odor	87%	86%	57%	84%
Can smell local drains	38%	72%	31%	49%
(If yes), is bothered by odor	88%	87%	82%	86%
Very satisfied with environmental conditions	43%	33%	77%	51%
Somewhat satisfied with environmental conditions	55%	41%	14%	37%
Not satisfied with environmental conditions	2%	22%	4%	10%

9. The Neighborhood Deal: A Plan To Improve Water Supply And Sanitation Service In Semarang

In order to describe a feasible neighborhood deal to survey respondents and community meeting participants, we used photographs, drawings, and detailed information about the process by which an improved water and sanitation system might be installed and operated in Semarang.[14] Enumerators provided this information to survey respondents in private, one-on-one interviews, while community meeting facilitators presented and discussed the deal with groups of participants in an open format.

Only 3% of survey respondents were familiar with the concept of a sewer system prior to their interview. Many respondents devoted significant time to studying the visual aids and asking questions about the system, which was described as having two components. A network of underground pipes would deliver potable water to households and would remove human wastes and waste water; a treatment plant would be constructed to treat waste water before it was discharged into the ocean. Respondents were told that such a system would provide a reliable and high quality water supply; improvements in neighborhood sanitary conditions; and a reduction in some types of water pollution and well water contamination. They were informed, however, that flood water drainage would not improve significantly as a result of the proposed improvements in water supply and sanitation service.

Once respondents understood how such a system would function in Semarang, enumerators described the process by which it would be installed and financed. Respondents were told to assume that the installation of an improved water supply and sanitation system would entail a two-stage process. First, RTs that wished to participate in the program would be required to raise the funds necessary to pay an assessment fee. Government would also contribute moneys, and these funds would be used to lay the neighborhood water and sewer lines from the major (trunk) pipes to each participating RT. Consensus must thus be reached within an RT for participation in the project, as every household in the district would be assessed a share of the installation fee, whether or not it decided to connect to the water and sewer system.

In crafting a credible neighborhood deal for improvements in Semarang's water supply and sanitation, we drew on the tradition of "self-help" programs extant in many areas of Javanese society. As one example, an influential grass-roots organization dedicated to issues of women and children's health and education (called the "PKK") has as one of its "ten principles" the idea of gotong-royong, or cooperation and empowerment through self-help programs. We thus developed a hypothetical program in which RTs that were willing and able to pay for water supply and sanitation improvements could choose either a "full-service" approach or a cost-saving "self-help" strategy in which community members would participate in digging trenches, laying pipe, and performing other un- or semi-skilled tasks.

Each RT that elected to participate in the program would thus decide whether to use an engineering contractor ("full-service") or an engineering consultant ("self-help"). Under the full-service plan, the contractor would design and carry out the installation of sewers in the neighborhood. With the self-help option, residents of an RT would share the responsibilities of digging trenches, laying pipe, and other un- or semi-skilled tasks, under the supervision of an engineering consultant. The assessment fee associated with the full-service option would be twice that of the self help plan. Residents of an RT would thus have to weigh the relative advantages of expertise, cost savings, and expediency in deciding whether the full-service or self-help approach were more desirable.

Second, once arrangements for an RT's participation in the program were finalized, individual households would face a choice of their own: private water and sewer connections would be provided only to those households desiring and able to pay for them. Households with existing water connections would have the option of adding a sewer connection. Those

[14] Appendix E presents copies of the photographs used by enumerators to describe the sewer system, including the wastewater treatment plant

without water service could have both a water and sewer connection installed (a water connection without an accompanying sewer connection was not offered as an option). Respondents were told that the decision to connect to the new system would be made at the household level, unlike the installation of neighborhood lines which would have to be performed for the entire RT. Thus, a respondent might contribute to his or her RT's assessment fee but subsequently decide not to pay the additional fees associated with connecting his or her household to the system.

The different costs and prices of the project were carefully explained to survey respondents and community meeting participants (see Table 6). A fixed assessment fee–the cost per household of having neighborhood water and sewer lines installed–would be charged to each household. Under the "full service" plan, this fee varied randomly between 50,000, 150,000, 300,000, and 500,000 Rp. for different questionnaire versions; that is, each respondent received only one of these four assessment fees. [15]

The respondent was also told that this fee could be halved if his or her community elected to use the "self-help" approach to installing the neighborhood lines. For example, a respondent who received the full service assessment fee of 300,000 Rp. also received a self-help fee of 150,000 Rp. The fee could either be paid in full at the start of the project, or could be financed over a two-year period.

In addition, households that did not currently have indoor plumbing and who wanted to take advantage of a household sewer connection would have to purchase and install a water-sealed toilet. (These costs were estimated at 250,000 Rp. per toilet.) For those households choosing to connect to the water and sewer system, a fixed connection fee would also be assessed. Those needing both water and sewer connections would pay a fee of 500,000 Rp., and those with existing water connections would only pay 200,000 Rp. fee for a sewer connection.

[15] It was not possible to vary prices among participants in each community meeting. All received a full-service assessment fee of 150,000 (and a self-help fee of 75,000)

Table 6: The proposed deals: Prices and costs for a household of improved water supply and sanitation service

		Who pays?			
		Homeowners		Renters	
Type of fee	Amount	With water connection	Without connection	With water connection	Without connection
Assessment fee*	50,000, 150,000, 300,000 or 500,000 for full service; 25,000, 75,000, 150,000 or 250,000 for self help	Yes	Yes	No	No
Connection fee	300,000 Rp. for water; 200,000 Rp. for sewer	Yes: 200,000	Yes: 500,000	Yes: 200,000	Yes: 500,000
Monthly fee	25% or 50% surcharge for HHs with existing connection; 15,000 or 25,000 Rp. average monthly charge for new connections	Yes	Yes	Yes	Yes
Water-sealed toilet	250,000 Rp.	Yes, if needed	Yes, if needed	Yes, if needed	Yes, if needed

* Could also be paid in 12 equal monthly installments with a 20% service charge.
US$1 = 2250 Rp.

A monthly service fee, comprised of a flat rate for sewerage and a use-based water fee, would also be billed to every connected household. As the amount of this fee would depend on the quantity of water a household consumed, the questionnaire was carefully worded to convey the idea that the prices cited represented estimates for average household consumption. For households with existing water connections, the fee for the improved system was described as a surcharge on their current water bill of either 25% or 50% in different questionnaire versions. For those without a household connection, average monthly water bills were estimated at either 15,000 or 25,000 Rp. As with the assessment fee, the surcharges and average bills were randomly assigned to different survey respondents.[16] A schematic of the twenty different questionnaire versions used for the household survey is presented in Appendix D.

Respondents were given several opportunities to ask for clarification of the project description and the financing requirements for the system. Once the scenario described was well understood by the respondent, the enumerator asked him or her the following question:

> Suppose that your RT had the option of participating in the improved water supply and sanitation project I have just described. Would you prefer that your RT not participate in this project; that your RT participate and hire an engineering contractor to carry out the work; or that your RT participate and people here carry out the work yourselves with the supervision of an engineer?[17]

A unique aspect of this part of the household survey was the classification of responses to questions about respondents' willingness-to-pay for improved water supply and sanitation. During questionnaire development, enumerators

[16] All community meeting participants with existing water connections received a monthly tariff equal to a 25% surcharge on their water bill. Those without connections were told that the average combined monthly bill would be 15,000 Rp

[17] Home owners would be responsible for the assessment fee and, ostensibly, for the indoor plumbing costs (i.e., renters were told they would only pay the connection and monthly service fees)

felt that some respondents would find it difficult to reject openly the improved water supply and sanitation program described in the questionnaire. Within the Javanese culture, they explained, it is common to provide an ambivalent rather than a negative response, with both the speaker and listener tacitly understanding the true intention of the comment. It was thus important for enumerators to distinguish this type of rejection from true uncertainty on the respondent's part. Working with the team of enumerators, we generated a list of ways in which residents of Semarang tell one another "No," and enumerators were asked to indicate on each questionnaire the precise manner in which a respondent provided his or her answer.

Next, respondents were asked to consider what their household would do if an improved water supply and sanitation system were installed in their RT. The costs of connecting were reviewed with the respondent, who was then asked the following question:

> Now I want you to suppose that households in your RT did decide to participate in this program, and that the water and sewer pipes were installed along the street. I want you to consider whether your household would connect to the pipes or not. Please consider this question carefully. If you would not be able to afford the connection, or if you feel you would have other, more important things to spend your money on, you should tell us that you would not connect to the system.

9.2 Household survey results

The results of the first question, regarding whether or not the respondent wished for his or her neighborhood to participate in the program for an assessment fee of a specified amount, are presented in Figure 7. Assuming that our strategy for classifying responses into yes and no categories is correct, the proportion of households that wish for their neighborhood to participate is relatively low at each of the specified assessment fees. Even with a very low per household assessment fee of 50,000 Rp. (US$22.22) for the full-service plan, only 53% of respondents favored their RT's participation in one of the two service programs (i.e., full-service or self-help). These were relatively evenly split between the full-service plan (58%) and the self-help plan (42%). As the assessment fee increases, the proportion of respondents favoring their RT's participation in the program generally decreases (which increases our confidence that respondents are listening to the questions asked and are attempting to give honest answers). [18] At the highest assessment fee of 500,000 Rp., only 10% of the respondents wanted the full-service plan, and only about 15% wanted the self-help plan.

Figure 8 shows that households that already have a private water connection were more likely to want their RT to participate than households without a private water connection. This was true at each of the four assessment fees. For example, at the lowest assessment fee of 50,000 Rp., over half of the respondents with private water connection wanted their RT to participate, whereas fewer than 20% of households without water connections supported the program. Figure 8 also shows that the effect of increasing the assessment fee is both more consistent and more pronounced for households with private connections than for households without private connections.

The data presented in Figure 8 are difficult to interpret given the small size of our sample. If it is true that, other things equal, households with private water connections have a higher demand for the neighborhood deal than do households without private water connections, this will have important implications for project design. It would suggest that the strategy of trying to get unconnected households to take both water and sewer services might result in many households taking neither, and that the attempt to bundle water and sewer services may be ill-advised. However, this result could simply be due to an income effect, i.e., households that have private connections are richer than households without private connections, and their greater wealth may

[18] This is not, of course, strong evidence that respondents' answers to such hypothetical questions are accurate indications of how they would behave if faced with a real choice. A recent paper by Griffin et al (1995), however, presents a rigorous comparison of respondents' ex-ante stated intentions in contingent valuation surveys versus their ex-post actual behavior. The authors found that answers to well-designed, soundly executed contingent valuation surveys provided fairly accurate predictions of how people would actually behave.

be the reason why they exhibit stronger demand for the neighborhood deal. This result could also be caused by a price effect; households with private water connections would incur lower connection costs as compared to those of households without private water connections.

Table 7: Proportion of respondents willing to connect by monthly tariff, questionnaire version and kelurahan

	Low tariff	High tariff	Total sample
Dadapsari	39% (25/64)	42% (24/57)	40% (49/121)
Bugangan	20% (9/45)	40% (17/42)	30% (26/87)
Sekayu	32% (18/56)	26% (13/49)	30% (31/105)
Total sample	32% (52/165)	36% (54/148)	34% (106/313)

Table 7 presents the results of the second valuation questions concerning whether or not the respondent household would connect to the new water and sewer system if it were available in the neighborhood. About one third of the respondents in the total sample expressed a desire to connect. This varied from 30% in Bugangan to 40% in Dadapsari. The variation in the monthly tariff did not have a statistically significant effect on respondents demand for connections. It is important to keep in mind, however, that this is just one of many costs and prices that households must consider in making this decision, and we have no reason to believe that it is the most important one. As with the first, collective decision regarding neighborhood participation, households with existing private water connections are much more likely to say that they want to connect to a sewer line than households without a private water connection are to indicate that they want water and sewer connections. For example, 75% of the homeowners in Sekayu with private water connections wanted to connect to sewer lines; only 15% of the homeowners without private connections wanted to connect to the water and sewer lines. In Dadapsari, 50% of the homeowners with private water connections wanted to connect to sewer lines; only 30% of the homeowners without private connections wanted to connect to the water and sewer lines.

Figure 9 shows how the results of the second valuation question regarding the household connection decision were affected by the four assessment fees used in the first (neighborhood participation) valuation question. The proportion of households indicating that they wanted to connect is lower at the highest assessment fee. Since respondents are told that they would have to pay this assessment fee regardless of whether they decided to connect, this reduction in the connection rate may be the result of an income effect.

Table 8 presents a cross-tabulation of the results of the two valuation questions. As indicated, 29% of the total sample said that they wanted their neighborhood to participate in one of the two service plans and that their household would connect (17% preferred the full-service plan and 12% the self-help plan). Fully 50% of the sample respondents said that they would vote against their neighborhood participation and, if their RT did participate, that their household would not connect. Interestingly, about one third of the respondents who voted for their neighborhood participation in one of the two service plans said that their household would, in fact, not connect to the new water and sewer lines.

Table 8: Proportion of respondents preferring no participation, full service, or self help by proportion who would connect to new system

Would your household connect to the new water/sewer system?	Would you want your RT to use the full-service plan, to use the self-help plan, or not to participate in the program to install water and sewer lines?			
	Full-service plan	Self-help plan	No participation	Don't know / Not sure
Yes, would connect	17% (n=54)	12% (n=37)	5% (n=15)	0% (n=0)
No, would not connect	6% (n=19)	9% (n=28)	50% (n=158)	0% (n=1)
Don't know	0% (n=0)	0% (n=1)	0% (n=2)	1% (n=4)

These results would seem to suggest that demand for improved water and sewer services is low, and that there is little household interest in sewer connections in Semarang. We believe, however, that such a conclusion is premature, and that the policy message from these preliminary survey results is more complex. The problem arises from the uncertainty involved in interpreting the no responses. For those answers that we recorded as no, Table 9 presents information regarding the frequency with which respondents gave a particular answer to the household connection decision question. As shown, there were 164 responses categorized as no. Of these, 32% said that the reason for their no response was that they could not afford it. Another 18% said they were in favor of the program, but the costs are too high. These responses, which represent one half of the no, seem to be clearly negative and correctly classified. Another 30% of respondents, however, said they needed to know what their neighbors opinions about the project were before they could make a decision about their position. During questionnaire development, our enumerators told us that this was a polite way of saying no, and that such a response should be classified as a rejection rather than as a not sure or don't know response. It seems to us, however, that assigning such responses to the no category is less certain than the responses related to budget constraints. Similarly, other responses listed in Table 9 also seem somewhat ambiguous (e.g., the current situation is satisfactory and I agree if participation is required). For this reason, we believe that the proportion of respondents classified as rejecting the improved water and sanitation service program is likely to be too high. That is, we believe that more households would favor the service programs than indicated by our summary of the household survey results.

Table 9: Description, frequency of No responses

Description	Number of times recorded	% of no responses
I cannot afford it	52	32%
I need to know others' opinion about program	49	30%
I agree, but the costs are too high	30	18%
Yes, if costs are reduced	11	7%
I have many children, expenses, etc., to worry about	8	5%
I agree, but current situation is satisfactory	6	4%
I agree, but without advance payment	4	2%
Yes, if payment period is extended .	2	1%
Yes, if participation is required by the government	1	<1%
I can pay but I want to avoid rumors (about my wealth)	1	<1%
TOTAL	164	100%

9.3 Community meeting results

All participants in the community meetings faced identical prices in the hypothetical neighborhood deal described for Semarang: a full service assessment fee of 150,000 Rp. and a self help assessment fee of 75,000 Rp.; water and sewer line connection fees of 300,000 Rp. and 200,000 Rp., respectively; an average monthly tariff of 15,000 Rp. without existing water connections and a 25% water bill surcharge for those with a connection; and installation costs for households needing to purchase a water-sealed toilet.

Meeting participants were asked to consider what they would do if faced with the choice of participating in this hypothetical new program. After discussion and debate, the group was asked if they would prefer their RT to participate in a "full service" arrangement or a "self help" arrangement; if they preferred that their RT not participate in the program; or if they were unable to reach consensus on the matter. The results of this question are provided in Table 10. Of the 316 individuals attending the community meetings, 27% were in favor of their RT's participation in the program. Of these, the vast majority (92%) preferred a "full service" arrangement. Thirty-nine percent were opposed to their RT's involvement with the program, as compared to over half of the household survey respondents. One third of the community meeting participants provided a response of "don't know" or "not sure" to the facilitators whereas only 2% of survey respondents exhibited such uncertainty.

Table 10: Proportion of community meeting participants preferring full service, self help, or no participation

	Full service	Self help	No participation	Dont know/ Unsure
Bugangan	22%	0%	19%	59%
Dadapsari	41%	0%	39%	20%
Sekayu	9%	7%	60%	24%
Total sample	24%	2%	39%	35%

In both the household survey and the community meetings, a greater proportion of Semarang residents oppose their RT's participation in an improved water supply and sanitation program than support it. The large percentage of "unsure" responses among community dialogue participants make direct comparison of these findings difficult. Whereas many different types of responses were classified by enumerators as "No" answers in the household survey (see above), community meeting facilitators were asked simply to record the responses of participants without interpretation. It might then be expected that the majority of 109 "unsure" responses obtained during the community meetings would actually indicate opposition to the program. At the same time, the open discussion format of the meetings may have afforded participants the opportunity to consider a relatively greater range of issues about the program (e.g., the views of their neighbors) and enabled them to consider their decision more thoroughly. This added information may indeed have left many unsure about their preferences for improved water supply and sanitation service.

10. Summary And Conclusions

Our work leads us to believe that, if the city's high economic growth rates continue, Semarang will almost certainly be sewered over the next 25-50 years. There is thus little question in our minds about whether a sewer network will eventually be constructed in Semarang; it is less clear, however, when and where construction should begin or the type of planning process that should be employed. This first phase of our study is an initial step in the process of learning more about household demand for improved water and sanitation services in Semarang, but we believe it provides some important insights into how the city's water and sewer network might evolve.

Although the sample of households we interviewed and the number of community meetings held were both quite small, the findings from our Phase I case study show that both the existing water and sanitation situation, as well as household demand for improved services, in Semarang are quite complicated. Only a minority of households have a private water connection, and many households want one. Some households without private connections obtain drinking and cooking water quite cheaply from public taps; others pay high prices to water vendors. Most households, even those with private connections, have their own shallow wells from which they obtain water for bathing and washing.

Regarding sanitation services, it is important to recognize that great strides have already been made in Semarang. Most households have water-sealed toilets for their exclusive use and the majority appear to be quite satisfied with their household sanitation situation. Nor do households seem overly concerned about neighborhood sanitary conditions, and by and large they are unaware of sewerage and wastewater treatment technologies that could improve the existing situation. Individuals in some neighborhoods are worried about flooding, and part of this concern is probably related to the spread of human excrement and wastewater that occurs during flooding episodes. This problem, however, is localized in specific districts of Semarang; the city's overall drainage is generally adequate. Large investments have already been made in constructing a system of large, lined drainage canals. Although these surface drains are heavily polluted, most people do not appear very bothered by the odors. The perceived benefits of surface water quality improvements in Semarang are thus likely to be low.

The results of both the household interviews and the community meetings appear to suggest that willingness to pay for a connection to a sewer system is low. Many people questioned whether the "neighborhood deal" proposed was a good idea even at very low prices. Among those households interested in having their neighborhood install new water and sewer lines, a diversity of opinion exists about whether to use an engineering contractor or a self-help approach. On the other hand, some households were enthusiastic about neighborhood sanitation improvements, and many survey respondents and community meeting participants were keenly interested to learn more about the sewerage and wastewater treatment technologies introduced.

In general, our results suggest that household demand for improved sanitation sewers is highly uncertain; people in Semarang are simply not yet of one mind regarding the need for new sewers in their neighborhood. Although more in-depth field work (including a survey with a larger sample) will help develop a better understanding of household demand, it is likely that a policy framework will have to be designed in the context of considerable uncertainty about demand. Our policy message might thus be summarized as: Demand is uncertain, so be careful.

Approaching sanitation planning in Semarang as an effort to design the best "neighborhood deal" has considerable advantages given this uncertainty in demand. If the municipal government offers neighborhoods the best deal it can afford and that is technically sound, then it would not be necessary to estimate demand neighborhood by neighborhood. Planners and engineers would need a rough picture of demand for improved services in order to anticipate what neighborhood deal they can offer and to decide where to build trunk sewers, but accurate predictions of connection rates in each neighborhood would not be required. Some neighborhoods would decide to install sewers now, others later, and some perhaps not at all. The sewer network in Semarang would thus begin with the neighborhood and move outward. [19] If trunk sewers are built along the existing main canals, many neighborhoods in Semarang will be able to connect to the larger sewer network without needing long interceptor sewers or waiting for other neighborhoods to install sewers.

We believe that these conclusions have ten important implications for the focus and direction of the Phase II Semarang study.

(1) Examine household demand for alternative "deal structures."

In order to implement a demand-driven planning approach in Semarang, more needs to be learned about exactly what kind of neighborhood deal households and neighborhoods would prefer. It is important to emphasize that the Phase I field research described in this report assessed demand for essentially one deal structure. This deal may well not be the one households would find most attractive. More research and discussion are needed to design the neighborhood deal that best serves households in Semarang, given the constraints faced by government. One issue of particular importance is whether it is desirable to offer different deals in different parts of the city. In Phase I we proposed a single deal to all households; however, the costs of installing sewers will be higher in some neighborhoods than others. Costs for one neighborhood may also differ depending on what other neighborhoods in the area decide to do. The possibility of offering different neighborhoods different deals raises a host of issues, such as fairness and practicality, that need to be carefully examined.

(2) Examine government perceptions of and attitudes toward alternative deal structures.

Our focus in Phase I was on households and neighborhoods in Semarang; we had little time to discuss in depth the concept of a neighborhood deal or alternative deal structures with government officials. In Phase II this task should be given top priority.

(3) Present respondents and participants in community meetings realistic cost estimates for different technological options.

In Phase I we gave respondents hypothetical prices and costs for improved sanitation services. In Phase II we intend to present households with realistic cost estimates for different technological options, based on actual neighborhood conditions. This will require that some preliminary engineering designs and cost estimates be prepared for the study areas selected in Semarang before the Phase II study begins.

(4) Estimate demand for private water and sewer connections separately.

In Phase I, following conventional wisdom, we assumed that new water and sewer services

[19] This approach would be similar to the Malaysia model (see Appendix A).

should be bundled, i.e., that households currently without a private water connection could not connect to the new water lines without also connecting to the new sewer lines. This issue needs to be rethought. Somewhat surprisingly, our preliminary findings suggest that the demand for the neighborhood deal is strongest among households that already have a private water connection. It does not seem that bundling water and sewer services increased demand of unconnected households for both services. In Phase II we intend to study this issue much more systematically, and to estimate demand for private water and sewer connections separately.

(5) Determine households 'knowledge of health risks, as well as which aspects of their current sanitation situation they dislike.

In Phase II we will focus more attention on respondents perceptions of the health risks they face from the current sanitation situation, and what aspects they would most like to see changed. This information is necessary to design the most attractive neighborhood deal for households; it should also prove valuable for any social marketing or publicity effort initiated to explain the final sanitation program.

(6) Determine the financing arrangements households prefer.

The question of financing arrangements for both the assessment fee and the connection costs needs to be thoroughly discussed with households. In Phase I our neighborhood deal offered financing of the assessment fee and connection costs for 1-2 years. This is likely to be too short a period. Other aspects of the financing package also need to be studied, such as the actual terms of the contract and what happens if a household defaults. We should also investigate whether the approach of charging an assessment fee for all households in a neighborhood, regardless of whether a household connects, is workable in Semarang. Are there alternative means of reducing the financial risk to the government that would work better?

(7) Determine how households and neighborhood leaders prefer to be involved with engineering contractors.

Much more needs to be learned about how neighborhoods and households would like to see both the full-service, engineering contractor and the self-help program options organized. For example, how would the community like to be involved in the selection of an engineering contractor? Over what time period would construction occur? Would the neighborhood be involved in authorizing payment to the contractor and/or in ensuring quality control?

(8) Determine the appropriate scale for the neighborhood deal.

In Phase I we assumed that the neighborhood deal could be offered to the RT, the smallest possible neighborhood unit. This may well be too small a group of households. The neighborhood deal should certainly be discussed at the RT level, but a collective decision may need to be made at either the RW or kelurahan level. In other words, a group of RTs may need to agree to participate in the deal before construction begins. The Phase II study should investigate this issue in detail.

(9) Pay greater attention to the question of whether gender differences in demand for improved sanitation services exist .

During the Phase I research it was not possible to organize community meetings with only women in the sample neighborhoods. In Phase II we intend to answer the question of whether women are willing to pay more or less than men for improved sanitation services, and, if so, why.

(10) Increase the number of respondents in the household survey and the number of community meetings in order to heighten confidence in the results.

Phase I was designed as a pretest; the sample sizes used for both the household survey and the community meetings were not intended to be sufficient for rigorous statistical analysis. In Phase

II we will increase these sample sizes in order to enable us to conduct econometric analyses of the data and to present results in which we have greater confidence.

In summary, we propose that Phase II of the Semarang study address these ten issues so that a neighborhood deal can be designed that forms the basis for implementation of the urban sanitation component of the Semarang urban redevelopment project. The ultimate design of the neighborhood deal will have to balance the interests of government with those of households and neighborhoods. One way that the results of the Phase II research might be used is to create a Blue Ribbon Commission of various stakeholders in Semarang, and to charge this commission with the task of designing the deal(s) that will be offered to neighborhoods and households. The results of our Phase II study could thus serve as input to the commissions deliberations.

A possible alternative to this proposed Phase II study of household demand for improved sanitation is a series of demonstration projects that would presumably install new water and sewer lines in selected neighborhoods in Semarang. In our opinion, however, it would not be advisable to initiate demonstration projects independently of the demand-driven planning approach suggested by the concept of a neighborhood deal. Unless carefully designed and implemented, demonstration projects could entail serious undesirable side effects. If some neighborhoods are provided with new services, for example, we believe that information about the deal implicit in such demonstration projects will quickly spread throughout Semarang; this could create difficulties for full-scale project implementation.

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DIRECTIONS IN DEVELOPMENT

Wastewater Treatment in Latin America

Old and New Options

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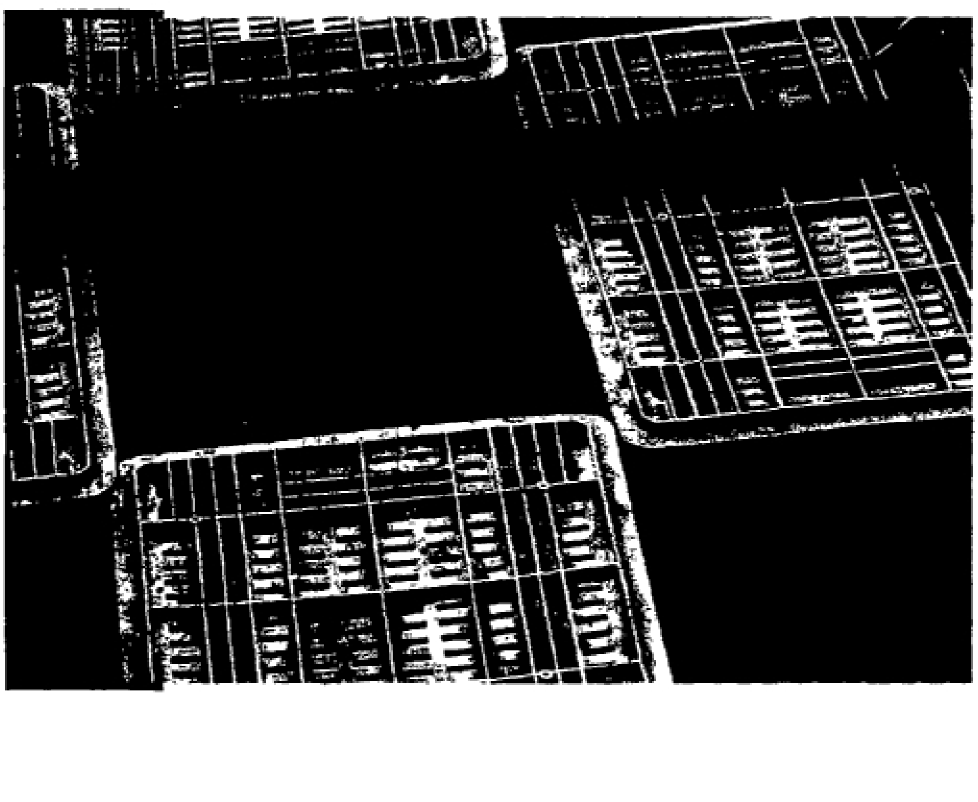

DIRECTIONS IN DEVELOPMENT

Wastewater Treatment in Latin America

Old and New Options

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Cover photograph: Detail of low-cost wastewater treatment in Tenjo, Colombia. Courtesy of the Inter-American Development Bank.

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Foreword

Municipal water supply and wastewater systems are typically made up of four major components: water production, water distribution, wastewater collection, and wastewater treatment. There is little doubt that in Latin America and the Caribbean wastewater treatment has lagged far behind the other three components. Although the share of the urban population connected to public water supplies and sewerage systems in Latin America and the Caribbean is about 80 and 50 percent, respectively, less than 5 percent of municipal wastewater is treated at any level whatsoever.

Many large cities in the region, such as Bogotá, Buenos Aires, Lima, Mexico City, and Santiago, discharge almost all their wastewater into the environment virtually untreated. The once pristine rivers on which many Latin American cities were founded are now polluted with domestic and industrial waste. The rivers that at one time represented a source of beauty and pride have turned into health hazards, with their contaminated waters used for domestic water supply, irrigation, or recreation downstream of major wastewater discharge points. Mexico City and Santiago in particular are known for practicing large-scale irrigation of agricultural crops using river water containing large amounts of untreated sewage.

This unhealthy and unsustainable situation has largely resulted from the low priority given to wastewater treatment. More urgent needs of the population, such as the provision of potable water and the sanitary collection of sewage, prevail, and wastewater treatment is invariably deferred.

Undoubtedly, the debt crisis of the 1980s also played a role. Public austerity forced the postponement of wastewater treatment plants, whose construction often involves large capital investments. The construction of a conventional secondary wastewater treatment plant for a population of 1 million requires a capital investment of about

$100 million, and its subsequent operation and maintenance demand an additional steady and substantial expenditure. Such costs have in the past been difficult to recover through user charges when consumers do not perceive the benefits associated with such investments.

In addition, decisionmakers are usually faced with the difficult task of selecting the most adequate wastewater treatment method among a wide array of options. The large variety of old and new methods can be confusing even for the professional, let alone the nontechnical policy-maker. This difficulty is compounded by the complex and variable nature of municipal wastewater, which contains both domestic and industrial wastewater, and by the continuous evolution of the standards established for the disposal and reuse of effluent.

The inability of public providers of water and sanitation services to respond to the growing threats to public health and environment has spawned a search for new alternatives. The most promising is the emergence of public/private partnerships, whereby the public sector redefines its traditional role of constructing wastewater treatment plants and providing water supply and sewerage services. While limiting its role to creating enabling legislative and regulatory frameworks, the public sector can encourage private firms to assume much of the responsibility for financing, building, operating, and maintaining wastewater treatment plants and water supply and sewerage systems in general.

The Technical Department of the Latin America and the Caribbean Region of the World Bank, together with host countries in the region, organized a series of seminars in 1995–96 to explore viable options to speed up wastewater treatment. The first such seminar took place in Santiago, Chile, in May 1995 and was cosponsored by EMOS, the municipal water supply and sewerage company of Santiago. The seminar was attended by professionals representing eight Latin American countries. A second seminar was organized in December 1995 in Campinas, Brazil, and was cohosted by the Secretaría de Política Urbana. A third seminar took place in Medellín, Colombia, in December 1996 and was cohosted by Empresas Públicas de Medellín.

These seminars focused on the technological and financial options available for municipal wastewater treatment and reuse. Invited speakers from the United States, the United Kingdom, Israel, and Latin American countries described traditional and innovative wastewater treatment and reuse schemes. In addition, a number of participants presented case studies of their own cities in Latin America. These included Buenos Aires and Mendoza (Argentina), Cochabamba (Bolivia), São Paulo (Brazil), Antofagasta and Santiago (Chile), Bucaramanga and Medellín (Colombia), Mexico City (Mexico), and Lima (Peru). Also discussed was the World Bank's technical and financial support of the wastewater sector development in Latin America.

The keen interest generated by these seminars within the Bank and in Latin America prompted the Technical Department of the Latin America and the Caribbean Region to prepare this publication. It reviews old and new technological as well as financial and implementation options available for wastewater treatment and reuse.

The general, simplified description of the available wastewater treatment technologies and implementation methods should interest both the professional and the nonprofessional, who will be obliged to devote more attention to wastewater treatment over the coming decade. We hope that this publication will clarify the debate and pave the way for investments in wastewater treatment to make up for the decades of neglect.

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Acknowledgments

Emanuel Idelovitch is presently an independent consultant. He was previously a staff member in the Latin America and the Caribbean Regional Office of the World Bank. He is now teaching a postgraduate class on wastewater treatment and reuse at the Faculty of Engineering of the Tel Aviv University in Israel. Klas Ringskog is the principal water specialist in the Technical Department of the Latin America and the Caribbean Regional Office of the World Bank.

A number of publications—too many to be listed—were used as general documentation for this report. However, one outstanding book deserves mention and has been consulted by many generations of sanitary engineers (including the authors of this publication) either as a textbook or for reference purposes: Metcalf and Eddy, Inc., *Wastewater Engineering: Treatment, Disposal, and Reuse* (1991).

The authors are grateful to all the speakers and participants who contributed to the World Bank wastewater treatment seminars held in Santiago, Chile (May 1995), in Campinas, Brazil (December 1995), and in Medellín, Colombia (December 1996).

Acronyms

BAYESA	Biwater Aguas y Ecología S.A.
BOL	build, own, lease
BOO	build, own, operate
BOOT	build, own, operate, and transfer
CTAPV	Compañía Tratadora de Aguas Negras de Puerto Vallarta
EMOS	Empresa Metropolitana de Obras Sanitarias [municipal water supply and sewerage company of Santiago, Chile]
ESSAN S.A.	[public company in charge of water supply and sewage disposal in Antofagasta, Chile]
GDP	gross domestic product
MERCOSUR	Mercado Común del Sur
NAFTA	North American Free Trade Agreement
RBC	rotating biological disks
SEAPAL-PV	Servicio de Agua Potable y Alcantarillado de Puerto Vallarta

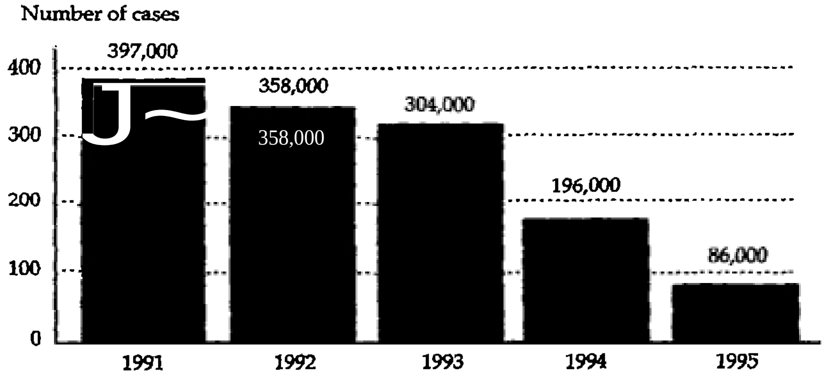
1
Introduction

After an absence of more than a century the scourge of cholera returned to Latin America in 1991. The detection of *Vibrio choleræ* in coastal Peru in January 1991 and the subsequent explosive epidemic throughout Peru proved to be only the start. Subsequently, cholera marched across Central and South America and has now become firmly established in a number of countries. It has appeared in all countries of the American continent with the exception of Canada and Uruguay.

The cholera epidemic did not occur because sanitary standards had suddenly deteriorated. It only proved what public health professionals had known all along: the deficiencies in potable water quality, public sanitation, and general hygiene were such that any water-related disease could establish itself overnight and then spread quickly. The decades of complacency and slow progress in increasing the coverage of water supply and sanitation came to fruition. The region was forced to acknowledge that more than 20 percent of the urban population was not connected to safe public water supply, that some 50 percent was not connected to public sewerage, and that virtually all municipal wastewater was disposed without treatment into natural water recipients.

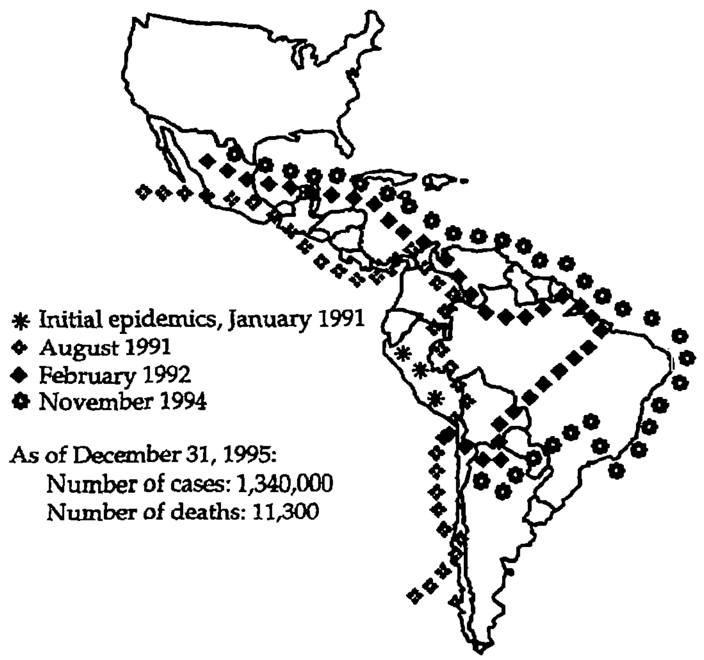
Like many other water-related diseases, cholera tends to be underreported. Even so, it is well documented that the epidemic has been costly for Latin America. From the start of the outbreak in 1991 through 1995 more than 1.3 million cases of cholera were reported, and total mortality was 11,300 deaths, about 1 percent of reported cases. The epidemic phase of the disease slowly receded, to be replaced by an endemic phase. From an annual high of nearly 400,000 cases in 1991, the incidence gradually dropped to less than 100,000 in 1995 (figure 1.1). Although the total number of cases is decreasing, the disease continues to spread geographically (figure 1.2).

Figure 1.1. Reported Cases of Cholera in the Americas, by Year, 1991–95



Source: Pan American Health Organization and World Health Organization 1996.

Figure 1.2. The Geographic Spread of the Cholera Epidemic in the Americas, 1991–95



2
Economic Aspects of Wastewater Treatment

The recent cholera epidemic serves as a grim reminder of the importance of wastewater treatment in the control and prevention of certain water-related diseases. Cholera and typhoid fever are both transmitted in a similar fashion through the "long cycle": *an infected individual* spreads the disease via *sewage,* which, if untreated and disposed inadequately, results in *water pollution.* Farmers often use polluted waters to irrigate food crops, such as in the arid areas around Lima, Mexico City, and Santiago. The long transmission loop is closed when individuals eat *food* that has been contaminated with polluted irrigation water or drink *water* that has been contaminated by sewage. More individuals fall sick, and the cycle is repeated.

The construction of sewerage systems alone cannot break this long cycle. Collecting the sewage of a city is of major benefit because it removes a potential health hazard from populated areas where the risk to public health is the greatest. But the threat to the population remains as long as the untreated wastewater is disposed into water recipients and then used to supply potable water or to irrigate food crops that are eaten raw.

Alternative on-site disposal systems such as dry latrines, cesspools, or infiltration wells used in conjunction with septic tanks do not remove the danger to public health either. Sewage from septic tanks may infiltrate the shallow groundwater from which potable water is extracted, resulting in groundwater pollution. In the short term, sewerage systems can even degrade the environment because piped collection and interception concentrate the sewage in a few disposal points. The end result is the deterioration of natural water recipients, such as rivers and lakes, whose natural purification capacity is exceeded.

The failure to treat wastewater is unsustainable. This was presumably evident in Western Europe and North America when these countries instituted large-scale wastewater treatment programs. Some 40 years later, Latin America is now facing the same situation: What is the optimal degree and technology of treatment? And how can the substantial financing needs be met at a time when pressing demands are threatening to crowd out funding for the wastewater treatment sector?

The Constituency of Wastewater Treatment

Large programs of wastewater treatment will not be implemented until a political constituency has been built to promote them and to secure the financial resources necessary for the first round of large-scale treatment works. Only recently has such a constituency begun to emerge in Latin America. Three groupings of opinion makers and lobbying groups favor sharply expanded wastewater treatment. The first group comprises officials and practitioners in the water supply and sewerage sector and public health officials who are fully aware that diseases are transmitted by the lack of wastewater treatment. The second group consists of related international businesses (agricultural exporters, contractors, and equipment manufacturers) that have a direct economic interest in wastewater treatment. The third group is formed by advocates of a sustainable environment, both individual consumers and representatives of government and nongovernmental organizations.

In recent years these three groups have been strengthened by the wave of democratization and the gradual opening of the region's economies, supplemented by regional trade agreements such as the North American Free Trade Agreement (NAFTA) and the Mercado Común del Sur (MERCOSUR) in the South. NAFTA in particular represents a determined effort to make major improvements in the environment.

The Public Health Costs of Water-Related Diseases

The 1991 cholera epidemic provided evidence of the very substantial costs associated with such explosive outbreaks. The direct and indirect costs of the Peruvian epidemic were particularly striking because they were so large in relation to the size of the economy. In Peru alone the costs were well in excess of the large number of cases registered. The economic impact was considerable. The country had to spend sharply more than usual in both curative and preventive health care. The high morbidity and the mortality of close to 3,000 persons implied a loss of economic production in addition to the suffering and hardship of the sick and their families. The losses affected the production destined for both domestic and external markets. Exports declined because of a temporary ban on imports of Peruvian food products and a drop in tourism.

Two available studies estimate the costs in Peru during 1991, the first year of the epidemic. The first study assesses the economic damage at about $500 million, while the second estimates losses at about $180 million (table 2.1; Petrera and Montoya 1991 and USAID 1993; all dollars are U.S. dollars). The estimates differ in how they quantify the economic losses due to higher morbidity and premature mortality and the losses in the tourism industry. The average of the two estimates yields a figure of about $340 million for the first year alone, or about 1.5 percent of Peru's gross domestic product (GDP).

The level of economic losses of 1.5 percent of GDP merits comparison with the level of investment in the Peruvian water supply and sewerage sector. Over the period 1971–78, Peru invested annually only $1.3 per capita in water supply and sewerage, equivalent to 0.18 percent of GDP. During 1985–89, at the height of the debt crisis of the 1980s, investments dropped further to only 0.15 percent of the country's GDP. Such low levels imply that the country was effectively disinvesting, because the annual investment was well below the level of capital stock depreciation. In addition, the sector agencies were chronically short of funds for operations and maintenance, which might ultimately have triggered the recurrence of cholera.

Table 2.1. Estimates of Total Economic Losses due to the Cholera Epidemic in Peru, 1991
(millions of U.S. dollars)

Type of losses	*Pan American Health Organization*	*USAID Water and Sanitation for Health Project*
Direct incremental health care	29	41
Lost production (morbidity and premature mortality)	260	85
Lost domestic production	47	27
Lost tourism	147	15
Lost exports	23	8
Total economic losses	506	176

Source: Petrera and Montoya 1991; USAID 1993.

In essence, by failing to invest at reasonable rates and to provide the funds and resources for safe operations, Peru exposed itself to water-related diseases. As a result, in the first year of the cholera epidemic alone, economic damage amounted to at least 10 times the level of sector investment. The achieved "economies" of deferring investment proved in the end to be penny-wise but pound-foolish.

Good Environmental Management and the Global Marketplace

The progressive integration of the Latin American and Caribbean economies with those of the Western Hemisphere and the global marketplace is a positive measure of how far the countries have come in making their exporting industries more competitive. However, in the short run the success of agricultural exports also means that the economies will have to use good environmental management as a competitive asset.

The point has not been lost on the countries in the region that have well-developed agricultural exports. Among others, Chile and Mexico cater to premium-priced off-season markets with high potential exports. Conversely, many years of efforts to develop markets could be lost if water-related epidemics close down exports. Agricultural interests are now pressing for better environmental management, including wastewater treatment.

The concern of agricultural exporters is acute because regional trading agreements such as the NAFTA are linked to improved environmental practices. The economic interests are not restricted to agricultural exports but span a number of exporting sectors, particularly tourism. The groups lobbying for improved environmental practices are not restricted to domestic producer and consumer interests. As the links with markets in industrial countries continue to grow, concerns about the health of agricultural workers in developing countries can be used to influence the consumers' choice of producers.

Growing Domestic Environmental Concerns

Most important, however, is the domestic awareness in all Latin America and Caribbean countries that gross contamination of rivers, lakes, and shorelines is unsustainable and exacts a heavy price on the health of the population and the aquatic ecosystems. Such environmental concerns are in part intuitive and in part based on empirical studies.

Studies are now available that show the impact of better sanitation on key welfare parameters such as infant mortality (Castañeda 1985). Although such studies have typically related health parameters to the coverage of public water and sewerage systems, it stands to reason that wastewater treatment is of considerable importance.

The Municipalization of Water and Wastewater Services

The trend in almost all Latin America and the Caribbean is to assign municipalities a greater role in the provision of a series of services. In recent years the legislation has changed so that, typically, municipalities are legally obliged to provide water supply and sewerage services, either directly or by delegating the responsibility to specialized public or private companies. In the short term the trend toward municipalization has created problems because the transformation has often been enacted overnight and has not allowed municipalities the time to prepare themselves for the added responsibilities.

The case of wastewater treatment is of particular concern because it is a technically sophisticated service for which qualified and experienced operators are scarce. Moreover, a particular municipality may be tempted to dispose its liquid waste in a river or lake without any treatment whatsoever. However, downstream communities suffer, and over time the natural self-purification capacity of recipients is exceeded. With worsening water quality, municipalities abstracting water downstream of the point of untreated effluent discharges incur steadily rising costs to make the water potable, without the certainty that all contaminants of importance have been removed. Under these circumstances it will become more and more cost-effective to treat wastewater and thus avoid the higher costs of treating potable water. It is well known that preventing contamination is a more economical and safer measure than correcting the damage after rivers and lakes have been polluted.

The special problems created by nonpoint-source pollution from agriculture and other diffuse sources are more difficult to address than the point-source pollution of urban wastewater. The nonpoint-source pollution will have to be reduced in parallel, but the measures will be different in nature and will focus more on modified techniques for applying fertilizer, herbicides, and pesticides and, ultimately, on modified methods of agricultural cultivation.

Given the substantial external costs of pollution, the municipalization of wastewater management has put a premium on solutions that are environmentally sustainable for entire river basins. River basin authori-

Table 2.2. Population Served with Public Water Supply and Sanitation in Latin America and the Caribbean, by Country, 1995

Country	*Population (millions, rounded)*		*Drinking water (percentage of houses connected)*		*Public sanitation (percentage of houses connected)*	
	Urban	*Rural*	*Urban*	*Rural*	*Urban*	*Rural*
Argentina	30.3	4.1	68	24	39	42
Bahamas	0.3	..	88	86	16	100
Barbados	0.1	0.2	98	98	4	98
Belize	0.1	0.1	89	51	44	21
Bolivia	4.2	3.0	74	42	41	39
Brazil	124.5	37.2	74	28	35	43
Chile	12.2	2.0	99	47	79	7
Colombia	26.4	10.3	86	32	65	27
Costa Rica	1.5	1.6	100	99	55	95
Dominican Republic	5.2	2.9	56	55	28	68
Ecuador	6.5	4.7	79	10	61	26
El Salvador	2.7	3.4	78	24	60	65
Guatemala	4.2	6.1	84	48	70	50
Guyana	0.3	0 5	77	69	27	28
Haiti	2.2	4.9	29	39	—	16
Honduras	2.8	3.1	77	66	50	71
Jamaica	1.4	1.1	57	53	34	65
Mexico	68.1	22.7	93	57	81	29
Nicaragua	2.5	1.6	86	28	34	28
Panama	1.6	1.4	98	73	64	81
Paraguay	2.6	2.4	59	6	20	44
Peru	16.8	6.6	63	31	59	23
Suriname	0.3	0.1	95	70	2	36
Trinidad and Tobago	0.9	0.4	90	88	32	92
Uruguay	2.7	0.3	90	—	56	—
Venezuela	19.8	1.7	73	79	62	60
Total	340.2	122.4	79	39	52	39

— Not available.
.. Negligible.
Source: World Bank estimates based on survey data from the Pan American Health Organization.

ties are now being considered and set up in a number of countries such as Brazil, Chile, and Mexico. Although embryonic, they offer considerable promise. They are loosely patterned on the German and French models, where the objective is to optimize the sustainable use of water resources in the basin. The key is to implement the "polluter pays" principle, whereby users of water are charged for the water they extract and for the pollution they cause. The experience so far with attempting to optimize the use of water has been mixed. Environmental concerns have been subordinated to the interests of producers of hydro-based electricity and to the interests of agriculture.

Levels of Urbanization, Water Supply, and Sewerage

Latin America and the Caribbean is the most urbanized region in the developing world. In 1994 the urban population was estimated to be about 74 percent and increasing. Such high levels of urbanization drive the need for sewage collection and treatment. Individual wastewater collection and disposal on the premises may be acceptable for some time in low-density rural and urban areas, but as population density and water use increase, the feasibility of individual or on-site disposal systems recedes, and collection and disposal become a public concern.

The sequence of public investments is well known. The coverage of piped water supply service increases, which prompts the need for a sewerage system. The sewage is collected and disposed first in nearby recipients and lakes and then farther and farther away from populated areas. Eventually, sewage has to be treated to remove the polluting substances so that the capacity for natural purification of the recipients is not exceeded.

Water Supply Levels

Latin America and the Caribbean has progressed far toward offering high coverage of both water supply and sewerage. In 1995 about 79 percent of the urban population lived in homes individually connected to piped water. In absolute number this meant that about 270 million out of an urban population of 340 million had piped water. Table 2.2 provides detailed estimates of the level of water supply service for the 26 largest countries in the region.

The service levels reported by the countries should be taken for what they are: estimates of varying quality. In past years individual countries have reported sharp changes from one year to the next, pointing to possible changes in definition. Definitions also may vary between countries and, thus, inter-country comparisons should be treated with caution.

Sewerage Levels

The level of sewerage coverage lags behind the level of water supply service by a wide margin. For the same year (1995), the urban population connected to public sewerage was estimated at about 52 percent. This means that about 180 million of the total urban population of 340 million had public sewerage. Almost 100 million people lived in homes connected to water, but not to public sewerage systems. The estimated level of sewerage service for the 26 largest countries in the region is detailed in table 2.2.

Wastewater Treatment Levels

The treatment of collected wastewater has hardly been initiated in Latin America and the Caribbean. Wastewater treatment plants are few and far between in almost all countries in the region. Few plants are operated properly. One evaluation of existing sewage treatment plants in Mexico estimates that only about 5 percent of the existing plants are being operated satisfactorily.

Less than 5 percent of all wastewater collected receives any form of treatment whatsoever. Because only about half of the urban population has sewerage and less than half of the wastewater generated is collected, a negligible percentage of the total volume of wastewater generated is treated.

Access to Safe Water and Sanitation Services for the Poor

In Latin America, approximately three-quarters of the population inhabit urban areas. Out of these one-third live below the absolute poverty line. This share of the population is growing. The urban poor lag significantly in the availability of safe water and sanitation services. In Latin America, only 18 percent of the urban low-income population has an in-house connection to safe water, compared with more than 80 percent of the urban high-income population. Similar results are found in the access to sanitation services. Improving the situation will be difficult because the urban poor often inhabit squatter settlements located on sites unsuitable for conventional development (steep hillsides, swamps, flood plains).

The skewed provision of services to the urban poor is not just a low-income country phenomenon. Colombia, a middle-income Latin American country, provides a good example. In 1992, 95 percent of the highest-income quintile lived in homes connected to the water supply compared with 62 percent of the lowest-income quintile. The situation was even more skewed for sewerage: an estimated 90 percent of the highest-income quintile was connected to a sewerage system compared with only 35 percent of the lowest-income quintile (Velez 1996).

The unequal access to public water and sewerage has implications for public health as well as for the human suffering that results from higher morbidity. The poor are more likely to have lower levels of sanitary education as well, and the result is a higher incidence of water-related diseases. This incidence will likely only be reduced through a three-pronged effort to improve the provision of potable water, the provision of sewerage, and the provision of extended sanitary education.

Past and Needed Investments in the Sanitation Sector

The return of cholera proved that the water supply and wastewater sector was investing well below what was needed to sustain service, let alone to expand coverage and improve quality. In retrospect the 1960s were dynamic years for the sanitation sector, in which relatively large investments were financed with national savings supplemented by bilateral and multilateral funds.

The trend of relatively high investment activity continued in the 1970s. The Latin America and Caribbean region invested on the order of $4.4 billion annually, in 1993 prices, in both water supply and sewerage. This level of investment constituted approximately 0.4 percent of regional GDP. Very little was invested in wastewater treatment, however. As a result, by 1978 about 68 percent of the total urban population was connected to public water supplies, and 36 percent was connected to public sewerage (Ringskog 1980).

The 1980s bore the consequences of the regional debt crisis. Investments were sharply reduced, and funds for operations and maintenance did not keep up with needs. Regional investments dropped to about $2 billion (1993 prices), equivalent to about 0.2 percent of regional GDP. All the same, the shares of the urban population connected to public water supplies and public sewerage slowly crept up to 79 and 52 percent, respectively, by 1995. In contrast, very little was invested in wastewater treatment.

As part of an initiative to raise the level of operating efficiency and service, the World Bank has estimated that about $12 billion annually would be required to raise water supply and wastewater standards to reasonable levels over a ten-year period (World Bank 1995): $5 billion for water supply and $7 billion for wastewater. Out of the annual wastewater investments of $7 billion, about $4.4 billion would be for sewage collection, $1.2 billion for wastewater treatment, another $1.2 billion for rehabilitation of existing but deteriorated installations, and the balance of $0.2 billion for rural sanitation.

These estimates assume that wastewater would be treated for 60 percent of the persons with public sewerage at an average cost of $70 per capita. These investments would be modest compared with the need for wastewater collection, but they represent a considerable increase from past levels. The construction and operation of wastewater treatment schemes would benefit both from technological advances and from the increased interest of private sector firms attracted to undeveloped markets in Latin America and the Caribbean. Supported at times by financing tied to the sale of equipment, foreign-integrated private firms could play an important role in allowing the region's countries to acquire cost-effective technology.

At the same time, countries need to develop the expertise needed to select between different treatment technologies in such a way as to dovetail with their capacity to pay for and operate the treatment works that will be built over the coming decade. The ability to select optimal treatment technologies requires a better understanding of the technological options available.

3
Technological Options

Selecting the appropriate process for treating a city's wastewater entails a careful process in which technical, economic, and financial considerations come into play. The uniqueness of each situation makes it difficult to define a universal method for selecting the most adequate type of wastewater treatment plant.

Ten Steps for Selecting the Most Appropriate Treatment Scheme

In most situations, the process of planning wastewater treatment involves ten major steps:

1. Determine the flow of wastewater
2. Determine the composition of wastewater
3. Determine standards for disposing or reusing effluent
4. Identify objectives and alternative processes for treating effluent before disposal or reuse
5. Determine the quantity and quality of sludge for each process
6. Determine standards for disposing or reusing sludge
7. Identify alternative processes for treating and reusing sludge
8. Identify alternative sites for treating, disposing, or reusing effluent and sludge
9. Determine the need for pilot studies and industrial pretreatment programs
10. Evaluate the technical and economic feasibility of each alternative and select the most attractive scheme.

Some of these steps are straight-forward, such as determining the flow and composition of wastewater. Others are much more involved and require considerable expertise, such as determining the appropriate standards and examining alternative technologies for treating wastewater and the sludge produced during the liquid treatment. Both conventional and innovative methods should be evaluated. The exception would be where land is so scarce and costly that land-intensive but capital-extensive technologies can be ruled out early on.

Step One: Determine the Flow of Wastewater

Determining the correct flow of wastewater to be treated is fundamental to estimating the scale of investments required. For this reason, the projections of wastewater flow should be based on adequate field measurements and should be linked explicitly to the city's investment program in expanding its water supply and sewerage collection systems.

It is necessary to assess early on whether the existing data on water production and consumption are realistic and whether they will remain valid in future years. Where the pattern of water consumption is wasteful, it is important to manage demand in order to reduce per capita consumption to reasonable levels and then to base the investment in wastewater treatment on the expected results of the effort to reduce wastage. Two variables are key to managing demand. The first is the extent of metering. Experience has taught that consumption is about 40 percent lower with metering than without it.

Similarly, the water tariff has a bearing on the amount of wastewater generated. The so-called price elasticity of demand measures the percentage change in the level of water consumption divided by the percentage change in the tariff. Its value varies with the type of consumption, among other things. Numerous studies have estimated the value of price elasticities (see, for instance, Cestti, Yepes, and Dianderas 1996). Long-term price elasticity of domestic demand has been found to be on the order of –0.4, showing that a doubling in real prices of the tariff can be expected to reduce per capita consumption 40 percent. The corresponding elasticities for different types of commercial and industrial consumers are even more significant, with values ranging from –0.6 to –1.2. These values are significant enough to be taken into account in the projections of future wastewater flows.

The counterbalancing effect of higher income on water consumption should not be forgotten. The analogous income elasticity of water demand measures the percentage change in per capita consumption divided by the percentage change in per capita income. Its value has been estimated at +0.3, showing that consumers are quick to add water-consuming fixtures and appliances as their income levels climb.

The level of the tariff is not the only determinant of the volume of wastewater generated; the structure of the tariff also has a bearing. The environmental impact of industrial effluents depends on their quality, the presence of toxic substances, and the location of the discharge, in addition to their quantity. For this reason pollution charges are often imposed as a binomial, where the total charge varies with the amount of pollution and the volume of wastewater. This gives polluting firms an incentive to reduce both their pollution loads and their volume of wastewater. In three industries in São Paulo, Brazil, the introduction of effluent charges reduced the consumption of industrial water 40–60 percent within two years.

Finally, the determination of wastewater flow will have to be closely linked to future coverage of the wastewater collection system.

Step Two: Determine the Composition of Wastewater

Wastewater comprises the water supplied for domestic, commercial, or industrial uses plus the contaminants added through that use. Wastewater may also contain storm water that has reached the sewerage system as well as groundwater that has infiltrated the underground sewage pipes. Domestic wastewater consists of about 99.9 percent water and 0.1 percent solids; the latter corresponds to a concentration of total solids of about 1,000 milligrams per liter or parts per million, which is typical for medium-strength municipal sewage. The solids in wastewater include settleable solids—large particles, which can be removed rapidly by gravity; suspended solids, which can also be removed by gravity but require longer settling times; colloidal particles, which can be removed from wastewater only by chemical coagulation or biological degradation; and dissolved solids. The concentration of suspended solids is a common parameter used to indicate the general quality of wastewater and level of treatment needed.

Most of the impurities in sewage are organic in nature. They include the main organic groups (proteins, carbohydrates, fats, and oils); some environmentally important substances, such as detergents, pesticides, and phenols; and numerous synthetic chemicals. Contrary to general belief, synthetic chemicals are generated not only by industries but also by households, which are using more and more household cleaning products that contain them.

Because of their great number and large variety, organic substances in wastewater are difficult to identify and measure. Only the concentration of certain organic compounds can be determined, and this requires sophisticated and costly techniques such as mass spectrophotometry, gas or liquid chromatography, and other emerging techniques. Therefore, for practical purposes, surrogate parameters are used to assess the concentration of organic substances in wastewater. The most common of these parameters are biochemical oxygen demand and chemical oxygen demand. Wastewater also contains inorganic substances as well as a large variety of microorganisms, including bacteria, helminths, and viruses, some of which are pathogenic to man.

Municipal wastewater from medium and large cities always contains a certain amount of industrial wastes that must be well known and characterized. If needed, industrial pretreatment should be imposed in order to ensure that the treatment plant will function properly.

Step Three: Determine Standards for Disposing or Reusing Effluent

Wastewater treatment is generally aimed at producing an effluent that complies with standards or guidelines for discharge into water bodies such as rivers, lakes, or oceans. When the effluent is to be reused, its quality must comply with standards set up for a specific purpose (irrigation, industrial, recreation, groundwater recharge).

The main objective of wastewater treatment depends to a great extent on the destination of the final effluent and the quality required by that destination. The common objectives, which are related to both aesthetic and health concerns, are to remove floatable material, suspended solids, biodegradable organic substances, and pathogenic organisms. A more recent objective is to remove nutrients (nitrogen and phosphorus), when the effluent is discharged into lakes or reservoirs. This prevents or limits the growth of aquatic plants and the proliferation of algae, which deteriorate the quality of the receiving water. Another objective is to remove toxic compounds, such as certain heavy metals and refractory organics, which must be treated by advanced methods, especially when the effluent is intended for reuse.

Quality standards are usually set up for industrial wastewater discharged into municipal sewerage systems, in order to ensure that heavy metals or other wastewater contaminants generated by industrial activity do not reach levels that may damage pipes, inhibit the biological treatment processes, remain in the effluent in higher concentrations than permitted, or accumulate in the sludge and limit or even prevent its disposal or reuse. The establishment of industrial discharge standards is important in order to promote industrial pretreatment programs and control certain industrial discharges, which may be critical for the operation of wastewater treatment plants.

The most common parameters used for monitoring the compliance with effluent discharge standards are the biochemical oxygen demand, suspended solids, and dissolved oxygen. As already indicated, biochemical oxygen demand is a surrogate parameter reflecting the content of biodegradable organic matter and the level of treatment achieved. Suspended solids measure the concentration of particulate matter in sewage, most of which is of organic nature. Dissolved oxygen levels are important mostly in connection with bodies of water used for fishing, because minimum levels are required for normal activity of fish.

The adoption of suitable effluent standards for each situation is critical in wastewater treatment in developing countries. Some countries have adopted no official standards at all, whereas others have adopted unrealistic standards established in the industrial world. The complexity of establishing rational effluent standards is best illustrated by the level of dissolved oxygen, which will eventually determine the acceptable level of biochemical oxygen demand in the effluent. First, the minimum level of dissolved oxygen required is not constant: it varies roughly between 2 and 5 milligrams per liter, depending on the fish species involved. Second, it depends on temperature. Fish require more oxygen at higher temperatures, which is when oxygen in water is less soluble. And third, lower concentrations of heavy metals are toxic to fish at lower levels of dissolved oxygen than at saturation levels. The self-purification capacity of rivers and the dilution of the effluent with the flow of natural water in the river must also be considered when setting up discharge standards. The river flow is constant when the river is regulated by an upstream reservoir, but in most cases there is a considerable difference between flows during dry and wet weather.

Step Four: Identify Objectives and Alternative Processes for Treating Effluent before Disposal or Reuse

Alternative treatment processes can be identified based on the quality of influent wastewater and the desired quality of effluent. The large variety of treatment methods include both old, traditional processes still in use as well as new, innovative processes.

Wastewater treatment is generally required to avoid or at least reduce the hazards created by the disposal of untreated wastewater into receiving waters or onto land. These hazards include aesthetic nuisances caused by large, floatable solids; malodorous gases released during decomposition of organic matter; pathogenic microorganisms that represent a public health risk; the growth of aquatic plants in receiving waters caused by nutrients; compounds that are toxic to people, animals, or crops; and adverse conditions such as the lack of oxygen in receiving waters.

It is particularly important to treat wastewater that is discharged into receiving waters used for drinking water downstream of the discharge site. Conventional drinking-water treatment technology cannot remove all the organic contaminants remaining in water after conventional wastewater treatment and after the self-purification and dilution in natural water courses. Some of these contaminants may have short- or long-term adverse effects on human health.

Similarly important is the treatment of wastewater destined to irrigate crops such as vegetables and fruits that are consumed uncooked. Even when waters such as rivers or oceans are used only for recreational purposes, adequate wastewater treatment must be provided. The common practice of discharging wastewater into the sea or ocean may adversely affect not only the use of beaches for recreational purposes but also the production of fish and shellfish consumed as a source of protein by humans and animals.

The particular case of industrial wastewater or of municipal wastewater with unusually high percentages of industrial discharges may require special analyses and the adoption of specific treatment processes for removing certain contaminants. In most cases, however, wastewater treatment methods and objectives are universal and have changed little in the last few decades.

Step Five: Determine the Quantity and Quality of Sludge for Each Process

Sludge—the by-product of almost any wastewater treatment process—must be quantitatively and qualitatively characterized for each process considered. There is a close connection between the treatment of liquid and the treatment of sludge. The optimization of a wastewater treatment plant refers to the treatment of both, which should minimize the quantity of sludge produced and yield a sludge cake of the highest possible quality, meaning as stable (minimal concentration of organic matter and pathogens) and as dry (maximum solids content) as possible.

Step Six: Determine Standards for Disposing or Reusing Sludge

There is growing concern that the standards for disposing sludge safely are as important as the standards for treating effluent. The setting up of sludge standards is a relatively new development even in industrial countries such as the United States. It is the result of the recent ban on dumping sludge in the ocean and growing awareness that global environmental protection can be achieved only by imposing limits on the disposal of both effluent and sludge.

Step Seven: Identify Alternative Processes for Treating and Reusing Sludge

Alternative treatment processes can be identified based on the quantity and quality of sludge produced by the plant and the quality of the sludge cake to be obtained after treatment. A sludge cake (semisolid sludge) is the output of the sludge treatment plant, because dewatering (extracting water from the sludge) is normally included in any treatment scheme. Without dewatering, transporting sludge to the final disposal or reuse site is generally not economical.

Step Eight: Identify Alternative Sites for Treating, Disposing, or Reusing Effluent and Sludge

After determining the specific destination of the treated effluent and sludge (disposal or reuse) and the alternative processes that would be considered, specific sites must be identified for the effluent and sludge treatment plants as well as for the final disposal or reuse of the two products (effluent and sludge).

Step Nine: Determine the Need for Pilot Studies and Industrial Pretreatment Programs

It is then necessary to determine whether laboratory or field studies should be undertaken for some of the processes considered. Such studies are usually needed for evaluating new processes and equipment, for which experience is still scarce but that seem promising for the conditions of the project, as well as for confirming or determining the performance of a certain process under the conditions prevailing in the project area (for example, temperature).

In large cities, where industries contribute a significant amount of wastewater, the enforcement of industrial pretreatment programs is essential for the successful operation of any treatment plant. The importance of such programs cannot be overemphasized in cities with large wastewater treatment programs. The main elements of a successful industrial pretreatment program are the following:

- A discharge inventory and information system
- An industrial discharge permit system establishing limits for discharging into sewers and requirements for presenting a compliance plan
- Self-reporting requirements that involve the use of certified laboratories
- Inspection and monitoring by the wastewater authority
- Sanctions for noncompliance
- Sewer use tariffs based on both the volume discharged and the organic load
- Industrial participation, for example, through a joint water quality council, in all phases of the program, including design, the setting of standards, and implementation
- Some form of technical and financial assistance for industries, particularly small and medium enterprises
- A training and institutional development program to help the wastewater authority prepare itself in this new area of responsibility
- Close and well-defined coordination with the environmental regulator responsible for ensuring that industrial wastes are not discharged into sewers as well as for the correct disposal of effluent and sludge.

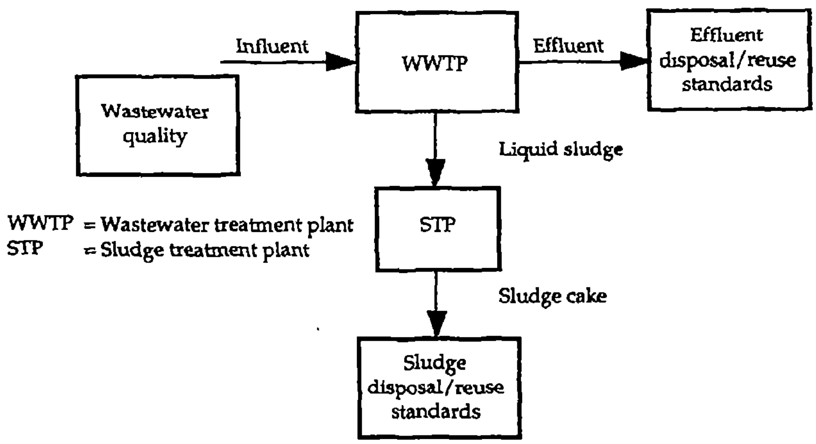
Step Ten: Evaluate the Feasibility of Each Alternative and Select the Most Attractive Scheme

The alternatives considered suitable for the project must be submitted to a full technical and economic feasibility analysis. The most attractive scheme is then selected based on preliminary designs and cost estimates. The present value of both capital investment costs and annual running costs must be taken into account. Other important factors must also be considered such as the environmental impact of the plant, the complexity of its operation, and its compatibility with existing installations.

Wastewater Treatment Methods

In a simplified manner, wastewater treatment should be regarded as two boxes, whose contents must be adequately defined (figure 3.1): the effluent or liquid treatment and the treatment of its by-product, sludge. Wastewater treatment methods are usually classified into four categories, in accordance with the order in which they were developed and applied and the degree of treatment they provide: preliminary or pre-

Figure 3.1. Wastewater and Sludge Treatment



treatment, primary treatment, secondary treatment, and tertiary or advanced treatment.

In the case of conventional methods, this classification is clear and adequate, because each stage of treatment refers to a well-defined technological process or processes. Pretreatment refers to the processes that remove large objects and usually includes at least bar screens and grit chambers. Primary treatment usually consists of primary sedimentation tanks, where particles settle as a result of gravity. Secondary treatment refers to biological methods such as activated sludge or trickling filters. Tertiary or advanced treatment generally refers to chemical methods that remove nutrients or toxic compounds or improve the overall quality of the secondary effluent.

This terminology may be confusing when unconventional treatment processes are used. Recent modifications of the most common secondary treatment method—the activated sludge—include the capability of removing nitrogen and phosphorus by biological processes, whereas chemical precipitation can be used not only as tertiary treatment but also as an enhancement of primary treatment or simultaneously with biological treatment. In such cases, the terminology should reflect the nature of the process, not its sequential order. For this reason, treatment methods are best classified as physical, biological, or chemical processes. Physical processes include screening, mixing, sedimentation, and filtration. Biological processes include all the aerobic and anaerobic processes whereby treatment is carried out by microorganisms. Chemical processes include flocculation, precipitation, and disinfection. A brief review of conventional wastewater treatment processes is given in the appendix. Several innovative wastewater processes developed recently and old natural processes adapted to modern use are described below.

Chemically Assisted Primary Sedimentation

Chemical treatment of wastewater is not a new idea. The process was known before biological treatment methods were developed but lost its popularity with the development of biological treatment methods such as trickling filters and activated sludge. When it became necessary to remove phosphorus at many treatment plants, tertiary chemical treatment (following biological treatment) regained part of its past popularity. Following the success of chemical precipitation in removing phosphorus, chemically assisted primary precipitation was also introduced, either to remove phosphorus or simply to enhance the removal of suspended solids and biochemical oxygen demand (see table 3.1). Numerous plants in Europe and the United States have recently implemented chemically assisted primary sedimentation.

Nitrogen Removal by Biological Methods

Because nitrogen removal by chemical methods such as ammonia stripping following high-lime treatment, ion exchange, or breakpoint chlorination is costly, an important research effort was made in the last decades to develop biological methods for removing nitrogen. These efforts were successful and brought about a series of modifications of the conventional activated-sludge process, which include either nitrification alone or nitrification combined with denitrification.

Although conventional activated sludge removes only the carbonaceous oxygen-demand substances (organics), incorporating nitrification

Table 3.1. Removal Efficiencies of Conventional and Chemically Assisted Primary Sedimentation
(percent)

Parameter	*Conventional*	*Chemically assisted primary sedimentation*
Suspended solids	50–60	80–90
Biochemical oxygen demand	30–40	50–80
Phosphorus	10–20	70–90

Table 3.2. Effluent Qualities of Conventional and Modified Activated-Sludge Processes
(concentrations in milligrams per liter)

Parameter	*Conventional*	*Modified biological nutrient removal*
Suspended solids	20–30	10–15
Biochemical oxygen demand	20–25	10–15
Chemical oxygen demand	80–120	40–60
Total nitrogen	30–50	3–10
Phosphorus	10–20	1–5

into the process (in either a separate or the same tank) can remove noncarbonaceous oxygen-demand substances such as ammonia and organic nitrogen. A small portion of the ammonia is removed, while the remaining ammonia is converted into the less harmful, oxidized nitrogen compound—nitrate (NO_3). The amount of energy consumed and the volume of tank required are higher in the nitrifying activated-sludge process than in the conventional process.

The more sophisticated nitrification-denitrification process includes not only the oxidation of ammonia to nitrate but also the biological conversion of nitrate into nitrogen gas that is released into the atmosphere.

Combined Nitrogen and Phosphorus Removal by Biological Methods

Perhaps the most interesting modification of the activated-sludge process is the simultaneous biological removal of nitrogen and phosphorus. This has been carried out successfully at several plants, where phosphorus is removed by bacteria, where biological denitrification takes place, and where carbonaceous organic substances are removed. There are several proprietary processes for this method and many alternatives, one of which has been applied in the large wastewater treatment and reuse plant in Tel Aviv, Israel. The results obtained with the modified process are compared with those obtained with the conventional activated-sludge process in table 3.2.

Natural Wastewater Treatment Processes

Most wastewater treatment processes are, in fact, man-made developments of natural processes. The two most common examples are the settling of suspended particles due to gravity and the biodegradation of organic substances performed by microorganisms.

Gravity particle settling occurs in almost all wastewater treatment installations. In grit chambers, it removes sand, silt, and those organic particles that settle like sand. In primary sedimentation tanks, gravity settling, assisted by natural flocculation, is the principal mechanism that removes particulate matter. In secondary sedimentation basins, it separates and settles the biological floc formed in the aeration tank. In chemical precipitation processes, it removes the chemical floc formed during coagulation and flocculation. And in all of these installations, as well as in sludge thickeners, it concentrates solids and separates water from solids. All sedimentation processes seek to produce simultaneously a clarified effluent and a concentrated sludge. Grit chambers, primary sedimentation, and chemically assisted primary sedimentation were developed from the natural processes of particle flocculation and gravity settling.

In all biological treatment methods, either aerobic or anaerobic microorganisms degrade organic matter present in wastewater and sludge. The activated-sludge process was developed based on observations of self-purification in rivers, where aerobic bacterial degradation occurs using natural sources of oxygen. Anaerobic sludge digestion was developed based on observations of anaerobic bacterial activity in river sediments. Trickling filters evolved from the disposal of wastewater on land, which was common practice at the end of the last century. And the process of disinfection was introduced after observing the natural decay of pathogenic organisms.

But along with the impressive advances and developments in man-made wastewater treatment processes in the last decades, some natural, old treatment systems are still being used successfully and should be considered as alternatives. However, most of these natural systems require large extensions of land, which may limit their applicability to small and medium-size cities.

Besides soil absorption, which is the natural process used in on-site disposal systems (cesspools and septic tanks), there are three major groups of natural wastewater treatment systems: stabilization ponds, land treatment systems, and aquatic systems. Stabilization or oxidation ponds are used extensively in Latin America and elsewhere. The great variety of pond combinations in use makes any systematic classification difficult. In principle, natural (nonaerated) ponds can be aerobic, facultative, or anaerobic. Aerated ponds—a man-made development of aerobic ponds—reduces the amount of land required by adding artificial aeration.

The great advantage of ponds over other treatment processes is their ability to remove pathogens without the need for chlorination, if the detention time of the effluent in the ponds is sufficient. Other advantages include their low capital investment and operating costs and their simple operation and maintenance. Their main drawback is the large extension of land they require, which makes them less suitable for large cities than for small and medium-size localities. One of the main dilemmas facing some Latin American cities is the choice between a conventional wastewater treatment plant of the activated-sludge type and lagoons, which are cheaper to build but require large extensions of land that may be unavailable or expensive. A relatively new system of natural stabilization ponds used extensively in Israel, and also in Spain, California, and Santiago, Chile, is the deep reservoir treatment, which consists of a deep stabilization pond (8–12 meters deep) used for both seasonal storage and effluent purification.

Land treatment systems are usually classified into three categories. Slow-rate systems refer to vegetation or crop irrigation using effluents; rapid infiltration or soil-aquifer treatment refers to groundwater recharge with effluent via spreading basins; and overland flow consists of spreading the effluent over sloped land covered with vegetation and collecting it at the bottom of the slope as surface runoff.

Aquatic systems usually include ponds with water hyacinth or duckweed, which have the capacity to absorb nutrients, heavy metals, and other sewage contaminants, and natural or man-made wetlands.

Sludge Treatment

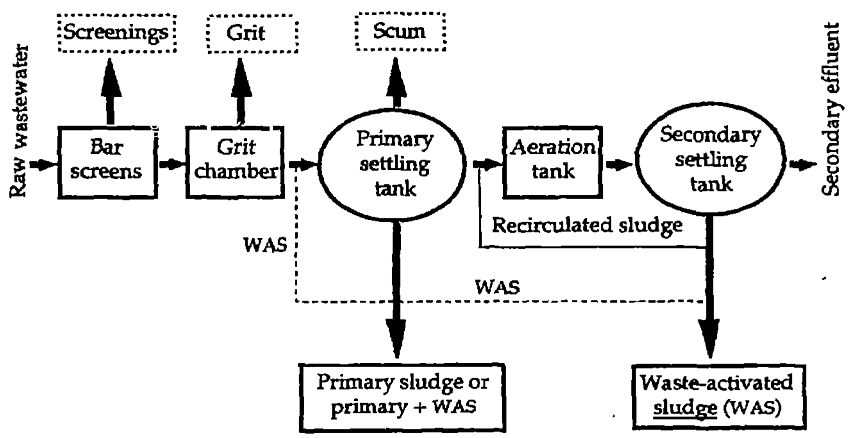
The most neglected aspect of wastewater treatment is the treatment and disposal of its main by-product—sludge. Sludge, which accounts for less than 1 percent of the wastewater flow, represents 50 percent of the treatment cost and 90 percent of the day-to-day problems for plant operators. Indeed, no wastewater treatment is complete without adequate handling and safe environmental disposal of the various types of sludge produced.

Preliminary treatment generates only a small amount of residuals, which include screenings removed from bar screens and grit removed from grit chambers. Primary treatment generates large amounts of primary sludge that are removed periodically from the bottom of the primary sedimentation tanks as well as minor quantities of oil, grease, and scum that are skimmed from the top of the primary sedimentation tanks. Biological treatment by the activated-sludge process generates large amounts of biological sludge that must be removed from the system continuously.

A distinction must be made between the main sludge produced in large quantities and the minor residuals produced in relatively small quantities (figure 3.2). The minor residuals are usually disposed on land in the vicinity of the plant or transported to the municipal refuse disposal site.

Primary and waste-activated sludge are voluminous mainly because they contain large quantities of water in addition to the solids removed during the treatment process. The typical concentration of solids in primary sludge is 4–8 percent. When waste-activated sludge is returned to the plant inlet and settles with the primary sludge in primary sedimentation tanks, the concentration of solids in the combined sludge is slightly lower (3–6 percent). The concentration of solids in waste-activated sludge is much lower—usually between 0.5 and 1.5 percent. When primary sedimentation is excluded from the activated-sludge process (such as in extended aeration systems), the concentration of waste-activated sludge is slightly higher—between 0.8 and 2 percent. These figures explain why the primary goal of sludge treatment is to concentrate the sludge, that is, to reduce its water content and volume. Almost all sludge treatment plants include sludge thickening and dewatering facilities to achieve this goal. Doubling the concentration of sludge solids—for example from 1 to 2 percent or from 3 to 6 percent—reduces the volume of sludge to half.

Figure 3.2. Sludges and Minor Residuals in Conventional Treatment

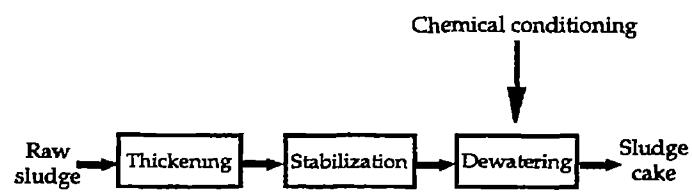


In addition to thickening and dewatering, sludge treatment also includes stabilization, which destroys volatile organic matter to minimize bad odors and reduce the number of pathogens. Stabilization is usually accomplished by biological methods (anaerobic digestion or aerobic oxidation) or by chemical methods such as lime stabilization. Stabilization also reduces the volume of sludge because some of the organic solids are destroyed in the process.

While thickening precedes stabilization, dewatering usually follows it (figure 3.3). Thickening is usually accomplished by gravity or by dissolved air flotation. Thickening is suitable for primary sludge, whereas dissolved air flotation may be efficient for waste-activated sludge, which is less concentrated and consists of lighter particles that may be easier to flotate than to settle by gravity. Thickening the waste-activated sludge, for example, can increase the concentration of solids from 0.5–1.5 percent to 2–3 percent.

Dewatering can be accomplished by natural methods or by mechanical means. Natural methods include sludge drying beds and lagoons. Some of the most common mechanical types of equipment used for dewatering are vacuum filters, pressure filters, belt filter presses, and centrifuges. Mechanical dewatering must be aided by conditioning the sludge chemically prior to dewatering. Chemicals used to improve dewatering include iron salts such as ferric chloride, lime, and polyelectrolytes. Dewatering the sludge with chemical conditioning may raise the concentration of solids up to 35–40 percent.

Figure 3.3. Sludge Treatment Scheme



(Percentage solids)

Type of sludge				
Primary	4–8	6–10	8–12	18–40
Waste-activated	0.5–1.5	2–3	4–5	15–20
Combined	3–6	4–7	5–10	15–30

Sludge heating, which is both a stabilization process and an alternative conditioning process that precedes dewatering, is rarely used because its cost is often prohibitively high.

Wastewater Reuse

In areas where natural water is scarce, municipal effluents are considered an unconventional source of supply that can be used either for local, specific needs or as an integral part of the regional water supply system. Even in areas where water from natural sources is plentiful, reusing wastewater can be the most efficient means of disposal from an environmental viewpoint.

When effluent is reused, its sale can offset the relatively high cost of wastewater treatment. However, institutional and legal problems may limit the sale of effluent to consumers. A distinction is usually made between incidental reuse, which takes place when wastewater is discharged into rivers or lakes from which water is withdrawn for irrigation or for potable supply, and deliberate planned reuse. Another, more important, distinction is made between direct and indirect reuse. In direct reuse, also referred to as pipe to pipe, the effluent from the wastewater treatment plant is supplied directly for irrigation or any other purpose. In indirect reuse the effluent is discharged into a natural water recipient (river, lake, aquifer) and is then reused, after undergoing self- purification and dilution with natural water.

The most attractive and widespread reuse of effluent is to irrigate agricultural crops, pastures, or natural vegetation. The main reasons are the following:

- Where crops need to be irrigated, water tends to be scarce, and treated effluents can substitute for freshwater
- Irrigation needs large amounts of water that are used only once, representing a large portion of total water demand in dry areas
- Agriculture benefits both from the water and the organic matter plus nutrients in the effluent
- The quality of water required by irrigation is relatively flexible, depending on the crops to be irrigated, soil conditions, irrigation method, and harvesting techniques.

An important distinction should be made between two types of irrigation with effluent: restricted and unrestricted. Restricted irrigation refers to the use of low-quality effluents in limited areas and for specific crops only. Restrictions are imposed on the type of soil that can be irrigated, the proximity of the irrigated area to a potable aquifer, irrigation method, crop harvesting technique, and fertilizer application rate. Unrestricted irrigation refers to the use of high-quality effluents, instead of freshwater, to irrigate any crop on any type of soil, which means without limitation.

Restricted irrigation is simple and low cost, but it is generally applicable only to small amounts of wastewater that can be used in specific locations, where areas and crops are well-defined and unlikely to change. The crop limitations imposed must be enforced and controlled. Farmers and agricultural workers must be trained to handle the low-quality effluent so as to minimize health hazards. Few farmers are willing to accept low-quality effluent in equal exchange for freshwater. In unrestricted irrigation, however, contact and even accidental drinking do not pose health risks, and the high-quality effluents should be acceptable to farmers.

Irrigation with sewage effluents is safely and widely practiced in many parts of the world, both in industrial and in developing countries. But at the same time, the dangerous practice of direct or indirect irrigation using untreated wastewater is also common in many of the region's cities such as Lima, Mexico City, and Santiago.

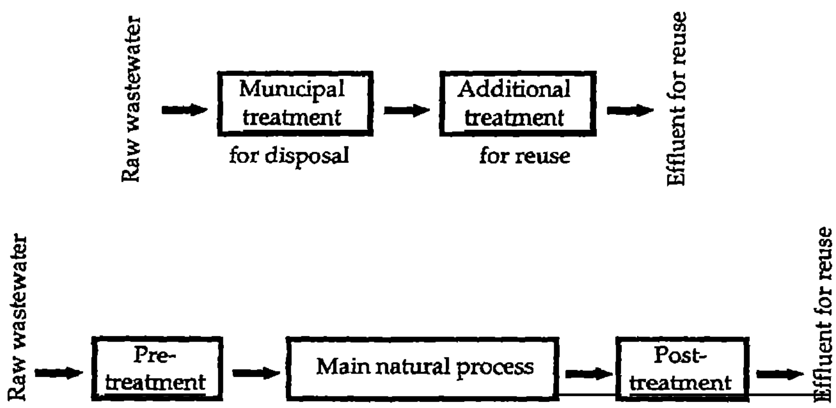
Effluents can also be reused for secondary industrial needs such as cooling water, recreational waters to be used for partial-body contact, municipal nonpotable uses such as landscape and golf-course irrigation, and domestic nonpotable water (flush toilets). The use of effluent for domestic nonpotable water, which has been introduced recently in specific locations in Southern California, implies the construction of a dual urban supply network, which could be economical for new urban areas in water-scarse regions.

Potable reuse of sewage effluents is technically feasible too, because a combination of advanced treatment processes can produce reused water of drinking water quality. However, such reuse is economically feasible only in situations of extreme water scarcity or an emergency. Moreover, the available analytical methods for detecting and measuring organic compounds in water cannot determine whether the residual organic carbon in the final product represents a long-term hazard to human health.

Wastewater Treatment Aimed at Reuse

Few widely known methods have been devised specifically to fulfill the objectives of wastewater reuse. The most common methods, which combine natural and man-made processes, were developed in connec-

Figure 3.4. Wastewater Treatment for Reuse



tion with requirements to control pollution in rivers and lakes. Wastewater treatment for reuse can be approached in two ways (figure 3.4). When conventional wastewater treatment for disposal is already in existence, tertiary treatment processes can be added to achieve a higher quality of effluent. Processes used in such situations include chemical precipitation with alum and polymers plus sand or dual-media filtration; direct filtration, in the case of low-turbidity effluents; lime treatment; and soil aquifer treatment.

When effluent reuse is considered before any wastewater treatment is in existence, special schemes can be devised to fulfill the specific purpose for which the effluent is destined. In most cases, this approach is the most efficient and economical. The most suitable treatment process for reuse, including natural treatment, can be adopted as the core process, preceded by minimal pretreatment and followed by posttreatment, according to needs and the final reuse of the effluent. Two such reuse systems were developed and implemented in Israel and are briefly described here: soil aquifer treatment (figure 3.5) and deep reservoir treatment (figure 3.6).

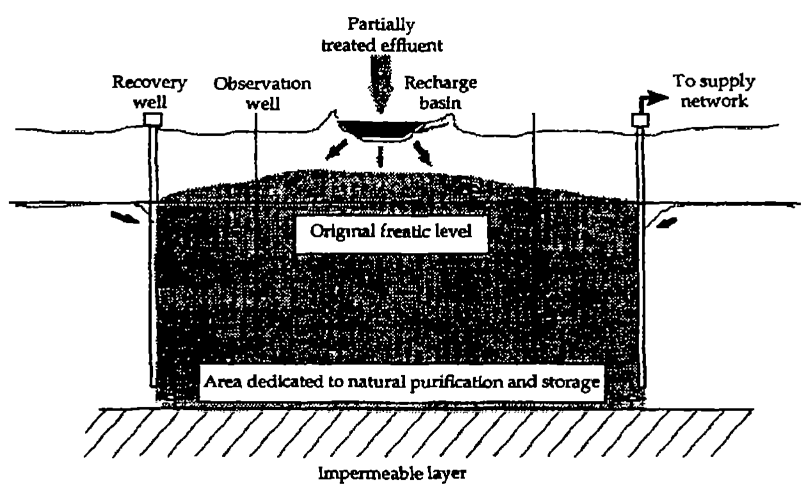
Soil Aquifer Treatment

Soil aquifer treatment is a special system consisting of groundwater recharge through spreading basins of partially treated effluent, which flows vertically through the unsaturated zone until it reaches the aquifer and then flows radially in the aquifer, and a ring of recovery wells surrounding the recharge basins and designed to pump the self-purified, high-quality water from the aquifer. As the name indicates, the purification effect is achieved by a combination of physical, chemical, and biological processes occurring in the soil and the aquifer. At the beginning of the operation, the wells pump native groundwater found in the aquifer. Later, they pump a mixture of native groundwater and increasing amounts of recharged effluent. In the steady-state phase, the wells pump large amounts of recharged effluent from the inner basin, where groundwater flow gradients are higher, and small amounts of native groundwater from the outer basin.

If the recovery wells are adequately spaced, the recharge and recovery facilities can be operated so as to confine the recharged effluent within the groundwater subbasin that is located between the recharge area and the recovery wells. This underground zone is dedicated to the treatment and storage of effluent and represents only a small percentage of the regional aquifer. The remaining groundwater basin is not affected and can continue to be used for potable supply. The reclaimed water, which can be traced and monitored by means of observation wells, is of very high quality and is appropriate for a variety of uses, including unrestricted irrigation. Accidental drinking of the reclaimed water would not involve any health hazard because of its high microbiological quality.

To achieve maximum infiltration and purification capacity, recharge basins must be operated intermittently, that is, flooding periods should

Figure 3.5. Soil-Aquifer Treatment Scheme



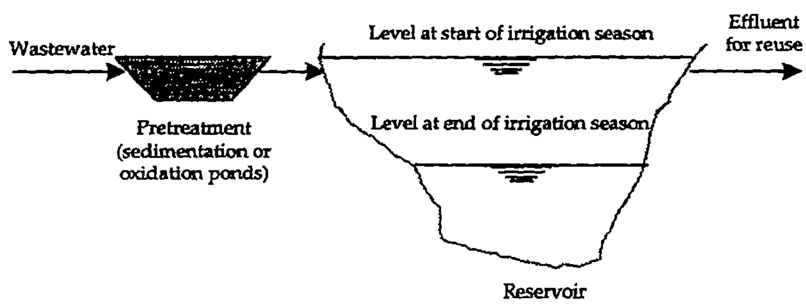
alternate with adequate drying periods. Continuous flooding of the basins would soon reduce the infiltration rates and require more and more land. It would also cause anaerobic conditions to develop in the aquifer, which would adversely affect the purification capacity of the system. This system has been successfully operated since 1977 in Tel Aviv's large reuse project (Idelovitch 1984). It is appropriate in areas where soil and groundwater conditions are suitable for recharge and where sufficient land is available for the recharge basins.

Many features of the soil aquifer treatment system are common to other systems, usually referred to as rapid infiltration. The most similar and well known of these systems has been investigated and applied in Arizona, where recharge basins are located in two parallel rows along the river bank and recovery wells are drilled in the river bed. In other systems, where groundwater is shallow, the effluent is collected by underdrains. In Germany and Holland, many cities use polluted river water after bank filtration, a concept similar to that of soil aquifer treatment. Advanced water treatment to produce drinking water is usually undertaken after bank filtration.

Deep Reservoir Treatment

One of the main components of any irrigation scheme with effluent is a seasonal storage reservoir, which is needed to balance the virtually constant supply of effluent with the great fluctuations in demand for irrigation, which depends on climate as well as crop patterns. Deep reservoirs were originally built in Israel to store effluents to be reused for cotton irrigation during a three-month peak summer season. It was soon observed that the quality of the effluent after several months of storage was significantly better than the quality of the influent to the reservoir, mainly with respect to organic content and number of pathogens.

Figure 3.6. Deep Reservoir Treatment Scheme



Since then, the deep reservoir treatment has been developed as an innovative scheme and been successfully applied in small and medium-size irrigation reuse projects. The reservoir is usually full at the beginning of the irrigation season and almost empty at the end. The depth of the reservoir varies between 8 and 12 meters. Most of the time the reservoir is stratified, with most of its volume acting as an anaerobic reactor and only the upper layer acting as an aerobic zone, from which the final effluent is extracted. The reservoir is totally mixed only during winter or transition seasons.

The pretreatment needed for wastewater before it is stored in the reservoir and the organic load on the reservoir must be carefully determined in order to avoid the creation of anaerobic conditions over the whole volume of the reservoir, which would result in low effluent quality and bad odors that can spread far from the plant.

Sludge Reuse

Sludge treatment and disposal have traditionally been the most neglected aspects of wastewater treatment. Until recently, both in industrial and developing countries, cities located close to the ocean disposed their sludge into the sea by means of more or less adequate sea outfalls. In inland cities in developing countries, sludge is usually discharged into lagoons or landfills. Limited sludge treatment is provided prior to disposal, usually including only gravity thickening and natural dewatering in drying beds (where climatic conditions are favorable).

However, like the liquid effluent, sludge can be treated and reused for a variety of beneficial purposes, without risk to human health and the environment. Anaerobic sludge digestion, which is a popular method of sludge stabilization, can generate methane gas that can be used to produce heat or power. Anaerobic digestion is particularly suitable in warm climates and for primary sludge, but it can also be used for combined primary and waste-activated sludges.

Applying sludge on cropland (agriculture) or forestland (silviculture), which is similar to using wastewater for irrigation, is a feasible alternative to disposal and should always be considered. Because of its high organic and nutrient content, sludge is particularly suited to the reclamation of marginal lands, such as saline or alkaline lands. When sludge is used on cropland, pathogens and heavy metals may be of concern. To reduce the danger of microbiological contamination of the agricultural produce, the sludge must be disinfected. Certain safety guidelines must also be followed. Control of industrial waste discharges is important to reduce the level of heavy metals and other toxic substances that may impair use of the sludge for application on land.

Wide-scale application of sludge on land requires the establishment of clear standards or guidelines, which are lacking in most countries. Even in the United States, where land application is used extensively, standards have been introduced only recently. Application of sludge in silviculture has the advantage of not posing health dangers, because the product does not enter the human food chain. Sludge can be applied to agricultural land either in liquid form (without the need for dewatering) or as sludge cake after dewatering. Suitable equipment for spreading the sludge and incorporating it into the soil or subsoil is required in both cases.

Sludge composting is another attractive reuse of sludge. Dewatered sludge is placed in a pile together with bulking material such as wood chips, straw, or recycled compost and is then aerated and stored for several weeks. During composting the organic matter present in the sludge is degraded and converted to stable end products. During composting, the temperature of the sludge rises to about 50–60 degrees Celsius, which reduces the pathogen content. Although the process is essentially aerobic, anaerobic zones in the sludge pile may cause bad odors—the main environmental problem of composting. To reduce the extent of the anaerobic zones and the danger of bad odors, in some composting systems, the sludge pile is periodically turned and mixed to improve aeration. The systems are referred to as windrow composting and as static pile composting.

The final product is a humus-like material that can be used to condition or fertilize the soil. Composting can be carried out with either unstabilized or prestabilized sludges. The joint composting of wastewater sludge and municipal refuse is also a common practice. The main effect of applying sludge on land is to increase crop production in agriculture and tree production in silviculture.

4
Options for Financing and Implementation

Constructing wastewater treatment plants is capital-intensive. Recent examples of competitively procured plants indicate an investment cost of $100 per capita of the design population. The investment cost per capita of the initial population can easily exceed $200, because it usually takes a number of years before the population actually served matches the design population. Where treatment plants are not bid competitively, the investment cost per capita is likely to be even higher.

To operate efficiently, such plants require competent operators and additional funds for current expenditures such as labor, materials, spare parts, chemicals, and energy. Improperly operated plants cannot ensure a high-quality effluent and a sludge that can be disposed or reused without representing a risk to public health or the environment. Only if such effluent and sludge are produced can the wastewater plant be considered successful and the capital used for its construction well invested.

Conventional Management and Financing of Public Projects

Until recently, wastewater treatment plants in developing countries, like any other component of a municipal water supply and sewage disposal system, were financed by governments or by government agencies. Typically, the public water supply and sewerage agency was responsible for undertaking preliminary studies as well as for designing and constructing the plant. In most cases, the public company contracted the studies and the design with a specialized private engineering firm, the construction with a private contractor, the equipment with one or more suppliers, and the supervision of the project execution with an engineering firm. In some cases, the contractor had to supply equipment as well. Only in isolated cases, and for relatively simple plants, did the public agency carry out the studies and designs in-house. Many contracts included the responsibility of the contractor to operate the plant, but only during a limited period (usually between three months and one year) for running-in the equipment and confirming the capabilities of the process.

In the past, treatment plants were often financed with the help of loans from international and bilateral agencies. Such financing was contingent on explicit or implicit central or local government guarantees that could be called in if the borrower did not service the debt in a timely fashion. In this way both lenders and operators were protected against all kinds of commercial and political risks. Such reassurances can give rise to complacency and even abuse because the government with its taxation and borrowing powers is thought to be able to bail out any shortfalls in the project's debt service. In addition to not promoting the best performance of suppliers, contractors, and operators, such all-inclusive government guarantees also use up too much of the government's limited guarantee capacity. In the process, they could crowd out other projects, for instance in the social sectors where government direct financing or guarantees are a must. Granting guarantees for revenue-generating projects that could well be financed without them does not represent an optimal use of the government's creditworthiness.

As a result of such full-recourse financing and public project management, many of the wastewater treatment plants constructed in developing countries have been plagued by cost overruns, implementation delays, and operation and maintenance difficulties. One of the major deficiencies of this scheme is that responsibility for the process selected is split between the consultant who recommended it and the contractor or equipment supplier who implemented it.

Turnkey Contracts with Government-Recourse Financing

"Turnkey" contracting represents a slightly more advanced conventional method, whereby a consortium of firms is responsible for both designing and constructing the plant. Although such schemes eliminate the possible conflict in responsibility for design, construction, or equipment, they do not guarantee long-range efficient performance of the plant. When such turnkey contracts are financed with full recourse to the government, they invariably suffer from the disadvantages of an unequal sharing of risks. The public sector will continue to bear the commercial risk during the operational stage. This is a weakness given the frequently poor performance of the public sector in the operations and maintenance stage.

Limited-Recourse or Nonrecourse Financing: BOOT Schemes

The difficulty of having the public sector finance such a large current and capital expenditure has made it natural to look at private sector participation as a way to finance water and wastewater projects in developing countries. Governments are keen to identify projects in sectors that have a potential to generate revenue, to become financially self-sustaining, and to be financed without public sector guarantees. The intent is to steer the government toward projects in sectors where there is no alternative to continued public sector management and financing.

The most extreme form is nonrecourse financing, where project sponsors and investors have no assurances from the government but depend entirely on cash generated by the project. This shifting of risk from the government to the private sector is in practice difficult to achieve. A compromise is then struck in which private sponsors and investors have limited recourse to the government, for instance in the form of a guaranteed minimum level of revenue.

A number of schemes exist in which the private sector finances, builds, and operates wastewater treatment plants. One common designation is BOOT, which stands for build, own, operate, and transfer schemes. Under a BOOT contract, a firm or a consortium of firms finances, builds, and operates the plant. The private sector retains ownership of the facility throughout the operations period and is allowed to charge a tariff sufficient to recover the investment. At the end of the operations stage the facility is transferred to the government, free of charge and in good operating order.

A variation is a BOO (build, own, and operate) contract in which private ownership is retained indefinitely. Other variations include BOL schemes where the private firm builds the project with government financing but then stays on to operate the plant while paying an annual lease fee. The gamut of schemes is limited only by the imagination of the parties.

The main objectives for introducing BOOT contracts in wastewater treatment are to make the operation and management of the plant more efficient, to attract new ideas and technologies, which could lower costs, and to finance the investment without public guarantees in any form.

Efficiency Gains of BOOT Plants

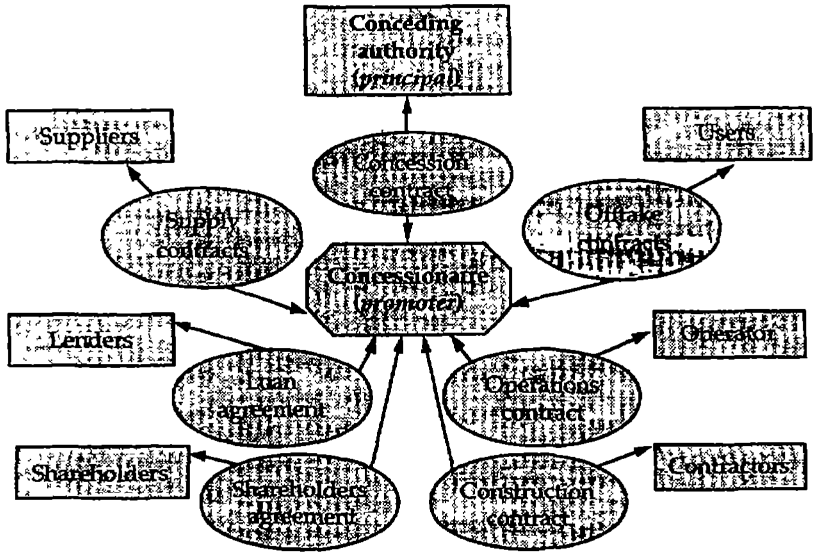
The efficiency targets are likely to be reached as far as the design, construction, and operation of the plant itself are concerned. In contrast, an efficient BOOT plant will not automatically resolve the larger problems of inefficiency in the total cycle of water supply and wastewater treatment. For instance, it is not uncommon to find that the water supply in a city is operated inefficiently, with levels of unaccounted for water as high as 50 percent, compared with efficient levels of 15 percent. In such a case, a BOOT wastewater plant built to treat the wastewater flow will necessarily be too large, at least initially. Similarly, it is not efficient for a city to contract with a BOOT operator to supply more potable water when rationing exists alongside unaccounted for water of 50 percent. In the same vein, a BOOT contract may not be the most efficient solution where consumption is excessive due to, for example, unrealistically low tariffs.

In situations like these, contracting with a BOOT operator should in no way remove the public sector's obligation to increase efficiency in those parts of the system that are not the responsibility of the BOOT operator. Ideally, BOOT contracts should not be bid until the system's efficiency is at a reasonable level. The difficulties are substantial, however, because achieving efficiency involves a combination of incentives for higher efficiency, better management in a number of areas, and also selective investments. Experience has proven that private operators are often more successful than the government in increasing operational efficiency.

General Principles of BOOT Contracts

A BOOT contract is a complex undertaking involving the *promoter*, which is given the right to build-own-operate a facility that provides a service in return for an agreed compensation before the facility is transferred back to the *principal*, which then concedes this right through a concession agreement. In turn, the promoter necessarily interacts with a host of other subsidiary parties during the course of complying with the concession agreement. The promoter, which can often be described as a capable "deal maker," attempts to reduce the substantial risks that it assumes under the concession agreement by entering into a series of subsidiary contracts. The most important of these subsidiary contracts are shown in the schematic representation of a full BOOT contract in figure 4.1.

Figure 4.1. BOOT Contractual Relationships



The first of the six subsidiary contracts may be a *supply contract* with the businesses or individuals that will be served by the facility. In the context of wastewater BOOT contracts, the supply contract will specify the quantity and quality of wastewater that will be supplied for treatment. In these projects the public authority or municipality granting the concession often represents the interests of all consumers. Instead of drawing up a special supply contract, the conditions and obligations of the clients will be included as part of the concession agreement. One such condition may be that consumers who have a supply of water are obliged to hook up to the public sewerage system in order to have their wastewater treated by the BOOT plant.

Under a BOOT contract for a wastewater treatment plant, the public authority is usually responsible for determining plant capacity, based on the estimated flow of wastewater. These estimates are of particular importance, because the public authority may guarantee the private contractor a particular level of wastewater flow to be treated and thus assume the risk of paying for the full service when the plant is used at less than full capacity.

The second type of contract is the *offtake contract*, in which the promoter agrees to supply output from the BOOT installation. Again, if the conceding party is a municipality, it often is in the interests of the community to have the wastewater treated at a certain, agreed level. The quality of effluent will then be specified in the concession agreement. The private operator must supply the quality of effluent defined in the BOOT contract or pay a penalty. To enable the private operator to do that, the public utility must ensure that the influent to the plant is of acceptable quality.

A major issue in municipal wastewater treatment in general, and in BOOT contracts in particular, is the need to control industrial waste. Heavy metals or other toxic elements discharged by some industries may, above certain concentrations, stop the biological treatment process or impair the quality of the final plant effluent or the sludge produced by the plant. In order to ensure uniform quality of the plant effluent, the public authority must ensure that only legal industrial discharges are allowed into the municipal sewerage network and treatment plant. The BOOT contract should establish clear responsibility for monitoring and controlling industrial waste.

A special offtake contract is relevant where water is so scarce that the treated wastewater can be sold for reuse, for instance in agriculture or industrial processing. The promoter can then sign a special contract in which it agrees to supply wastewater of a certain quality and in amounts specified by time period.

The third type of contract is the *loan agreement*, in which lenders commit themselves to finance the construction of the BOOT facility. Often a lead lender will attempt to spread its risks by syndicating the total amount of the loan over a number of lending institutions. The private consortium will usually raise a large percentage of the financing required for the plant from commercial banks, as well as from bilateral and multilateral lenders, such as the International Finance Corporation. The duration of a BOOT contract should equal the period of time needed to allow the consortium to pay back the debt incurred and return the equity investment. BOOT arrangements represent a substantial risk for the private firms involved if there are no assurances that the investment will be recovered during the lifetime of the project.

The fourth type of contract is the *shareholders' agreement*, in which investors agree with the promoter to provide the specified amount of equity needed to construct the BOOT facility. The necessary amount of equity is often a consequence of the demands of either the lenders or the principal. Both have an interest in ensuring that the promoter secures a sufficient proportion of the investment financing as equity to provide a cushion against unfavorable developments in the project's cash flow. At times, the promoter will secure some equity from contractors or equipment suppliers that have an interest in having the facility built.

The fifth type of contract is the *construction contract*, in which the promoter passes on the construction risk to an experienced contractor. The sixth and final type of contract is the *operations contract*, in which the promoter secures the services of a specialized firm to operate and maintain the facility. Through a BOOT concession agreement, the principal actually procures a range of services such as financing, construction, operations, and marketing. Only very large international firms can provide the full range of such services in-house. In other instances the promoter will often form a consortium of firms such as civil works contractors, equipment suppliers, plant operators, and both foreign and local lenders and investors.

Risks of BOOT Wastewater Treatment Projects

A BOOT contract, like any other form of private sector participation, involves certain risks both for the private and for the public sector. A successful BOOT will depend to a great extent on how well these risks can be quantified and mitigated. Careful analysis of the risks involved should be carried out early in the process, and risks should be shared between the private and public sectors following the principle that whoever can control or manage the risk best should assume it and receive adequate compensation for doing so.

The chief planning tool for analyzing the risk associated with a BOOT project is the project's cash flow. Both equity investors and lenders look to cash flow as the main guarantee of a return on their investment and of timely debt service. There is a difference, however. Equity investors are apt to make their decisions on the financial rate of return of the cash flow over the concession period. A high rate of return may result even if the cash flow in certain years is in deficit. In contrast, lenders study the annual cash flow carefully and decide whether to lend or not based on the likelihood that their loan will be serviced in an orderly fashion. Because long-term debt has a fixed remuneration and does not enjoy the upward potential that equity has, it is more difficult to attract. For this reason, cash flow becomes the centerpiece for analyzing BOOT projects.

Illustrative Cash Flow in Wastewater Treatment Projects

Table 4.1 shows a typical cash flow for a wastewater treatment project. Typically, a BOOT concessionaire will commit itself to treat a daily contractual volume of sewage of certain characteristics to comply with

Table 4.1. Cash Flow in a Wastewater Treatment Project

	Volume of wastewater treated
x	Average tariff for wastewater treatment
=	Gross operating revenue
–	Operating expenses
=	Gross internal cash generation
–	Interest payments
–	Amortization of loans
–	Income taxes
–	Complementary investments
–	Dividends paid to investors
=	Surplus for concessionaire/investors

stipulated standards of effluent quality. In return, the concessionaire will be compensated with a wastewater treatment tariff. This tariff is typically the criterion for selecting among BOOT concessionaires that bid for the concession.

The concessionaire will have to pay operating expenses and is then left with a gross internal cash generation. The internal cash generation is likely to be used in a strict order of priority. First, the concessionaire will be obliged to use the internal cash generation to pay interest on any loans contracted to construct the wastewater treatment facility. Second, the concessionaire will have to amortize the loans according to the agreed conditions. Lenders are exceedingly sensitive that debt service be paid on time and will reserve the right to call in the entire loan if the concessionaire or promoters fail to service debt in a timely fashion. Third, the concessionaire will likely be liable to pay taxes. Fourth, the concessionaire will need to invest in complementary works as demand grows over the concession period.

The concessionaire will likely attempt to finance such investments out of the internal cash generation. When complementary investments are so large that they cannot be financed out of retained cash, the concessionaire will likely attempt to borrow additional amounts rather than to contribute any additional equity. Additional borrowings should become easier to secure as the concessionaire establishes a track record and as the regulatory and tariff regimes are successfully tested. Often different borrowings receive different priority claims on the available cash. Senior debt has first claim, mezzanine debt has a lower priority, while subordinated debt of different types has still lower priority. Some subordinated debt approaches equity that has the lowest priority. Only after all kinds of lenders, taxes, and complementary investments have been satisfied will the concessionaire or project sponsor be able to receive dividends on its equity investment.

Risk Analysis

The cash flow of a typical wastewater treatment project is subject to many risks (table 4.2). Each item can vary depending on the magnitude of the risk. Both the public authority and the private operator incur risks under a BOOT contract. The risks will be analyzed from the vantage point of each of the two parties, placing special emphasis on the promoter's risk, which is usually the greatest.

Types of Risk

First, the amount of wastewater to be treated can be different from the amount envisioned in the contract. This type of risk is often referred to as *market risk*. Not only the volume treated but also the quality can be different. For instance, the wastewater may contain substances from industrial effluents that may harm the biological treatment process employed.

Second, the approved tariff actually paid can vary from what was assumed in the original cash flow calculations. For many types of infrastructure projects, the risk of tariff variations is determined by market competition, such as in transportation projects with competing modes

Table 4.2. Types of Risk in a Wastewater Treatment Project Cash Flow

Item	*Type of risk*
Volume of wastewater treated	Market
x Average tariff for wastewater treatment	Market (free competition) Political (under regulation)
= Gross operating revenue	
– Operating expenses	Operational/technical
= Gross internal cash generation	
– Interest payment	Financial
– Amortization of loans	Financial
– Income taxes	Political
– Complementary investments	Construction
– Dividends paid to investors	Political and transfer
= Surplus for concessionaire/investors	

of transportation. In the case of wastewater treatment, where one client, typically a municipality, has committed itself to pay a certain tariff, the risk is *political* in the sense that the concessionaire is relying on the stability and good faith of the methodology and its application in the calculation of tariffs.

There is, of course, always the risk that the client will not be able or willing to pay according to the volume of wastewater treated and the agreed tariff. BOOT contracts are usually signed by the promoter with one client, which could be a utility or a municipality. This *payments risk* can be considerable in the case of municipalities with a poor record of managing their affairs in an orderly fashion. The payments risk of municipalities is a good deal higher in developing than in industrial countries, where municipalities are careful not to endanger their access to credit markets by failing to honor their financial commitments in a timely and orderly fashion.

Third, the level of operating costs can differ from projected levels. Whenever the characteristics of the received wastewater prove to be at variance, operating costs will be higher to enable the operator to comply with the stipulated effluent standards. There is also the risk that the treatment technology employed will not yield the expected results even in cases where the wastewater characteristics are within the contractual parameters.

Fourth, interest payments will fluctuate over the life of the BOOT contract. This can best be described as *financial risk* because it depends on the financial conditions negotiated and on the evolution of financial markets. BOOT projects typically require long contract periods to allow the original investment to be recovered without resulting in such high tariffs that the consumers' capacity to pay is exceeded. However, financial markets in most developing countries are so unstable that few financiers are willing to lend medium-term funds or agree to fixed-interest conditions.

Fifth, an *exchange or currency risk* often arises when borrowings and equity contributions are in foreign exchange. Borrowings in external markets may often be the only way of obtaining reasonable maturities because developing countries often have no medium- or long-term credit market. Foreign borrowings are extremely vulnerable to sharp adjustments in exchange rates. Coverage against such exchange risks is prohibitively expensive or unavailable, except possibly over the short term.

Sixth, there is a risk that the government may modify its tax regime, which could affect the liabilities and cash flow of the concessionaire. Seventh, whenever works need to be built there is a *construction risk*. This risk is true primarily for construction of the initial wastewater treatment plant. Eighth, foreign investors are subject to the risk of not being able to convert their surplus local currency into foreign currency. This *transfer risk* arises because wastewater treatment projects typically earn revenue in local currency but frequently involve foreign investors or operators that wish to be compensated in foreign currency. The risk arises because a country may not be able to attract enough foreign currency to allow all those wishing to purchase foreign currency to do so.

Risks may usefully be grouped into two major categories: global risks that vary with the political and economic situation in the country and project risks that are specific to the BOOT facility.

Level of Risks

The level of risks will vary among the different items of the wastewater treatment project (table 4.3). First, there is the risk that the quantity of wastewater will be different from the projected levels. There could be many reasons for variances. For instance, the amount of water consumed can decrease if water tariffs are raised. This sensitivity of water demand to tariff changes is measured by the price elasticity, which is calculated as the ratio between the relative change in water consumption and the relative change in water price. The price of water will also include the sewerage tariff whenever water and wastewater services are charged as a combined tariff. The short-term price elasticity is around –0.2, which implies that a doubling of the tariff could be expected to reduce the

Table 4.3. Level of Risks in a Wastewater Treatment Project Cash Flow

Item	*Type of risk*	*Level of risk*
Volume of wastewater treated	Market	Medium
x Average tariff for wastewater treatment	Market/political	High
= Gross operating revenue		
– Operating expenses	Operational/technical	Medium
= Gross internal cash generation		
– Interest payments	Financial	High
– Amortization of loans	Financial	Medium
– Income taxes	Political	Low
– Complementary investments	Construction	High
– Dividends paid to investors	Political/transfer	Medium
= Surplus for concessionaire/investors		

consumption 20 percent. In the longer term the price elasticity of demand is higher, or -0.45.

Where the tariff for wastewater is based on the amount of pollution discharged, the amount of wastewater could also change. The level of effective metering has a significant impact on the level of consumption. In the short term, metering can be expected to reduce average consumption around 40 percent—and in the longer term about 50 percent—compared with the situation in which consumption is completely unmetered.

Given the sensitivity of water consumption to price and metering, the level of risk must be rated medium. However, treatment projects are typically built to address a problem that already exists: the environment is polluted by the unsanitary and unsustainable disposal of wastewater. This makes the volume of wastewater to be treated a better-known quantity than in BOOT projects that aim to satisfy a demand to be developed. In addition to the risk that the quantity of wastewater may vary from forecasts, there is the additional risk that the characteristics of the wastewater will be substantially different from the characteristics on which the treatment technology is based.

Second, there is also the substantial risk that tariffs may lag those projected, which could occur for several reasons. Tariff setting is often politicized, and authorities may wish to slow the rise in tariffs in the belief, for example, that this will help slow inflation. Where tariff increases are authorized in line with projections, there is the risk that consumers will not be able to pay them. The risk of tariffs that are driven by short-term political considerations and the payments risk combine to create a high risk that tariffs may lag forecasts.

Third, there are operational risks in the sense that the treatment technology will prove unable to meet the contractual effluent standards or that the level of operating costs will be higher than projected. With an experienced specialized operator, these operational risks are at the most medium, particularly if the operator is part of the promoter consortium and has been involved in designing and constructing the treatment facility.

Fourth, the financial risks associated with volatile interest rates are high. The promoter faces a dilemma in trying to reduce these. If much of the financing is sought in domestic financial markets, interest rates will be considerably higher and more volatile than they are in international capital markets. If much of the financing is sought on the international capital markets, which have lower interest rates and less volatility, a foreign exchange risk is created. If exchange rates are realigned substantially, the impact on the BOOT project's cash flow can be severe and swift.

Fifth, the construction risk must be rated as high.

Mitigation of Risks

Risks are inimical to economical and efficient project construction because all parties require compensation to assume risks. It is therefore natural to attempt to reduce risks from the outset because lower risks will reduce the level of compensation demanded by project sponsors, operators, and lenders. Table 4.4 illustrates ways to mitigate or reduce risks.

First, market risk in the form of lower-than-expected wastewater flows can typically be reduced through judicious coordination of the investment programs that connect customers to the sewerage system. Failure to do so may result in underutilized treatment facilities. Even with good coordination between wastewater collection programs and the BOOT treatment plant, the promoter will often try to obtain a guaranteed level of income through a take-or-pay contract in which the principal, often a municipality, commits itself to pay a minimum amount irrespective of the volume of wastewater treated.

Second, the high risk for the concessionaire of not being able to charge and collect adequate wastewater treatment tariffs can be reduced con-

Table 4.4. Reduction of Risk in a Wastewater Treatment Project Cash Flow

Item	*Type of risk*	*Reduction of risk*
Volume of wastewater treated	Market	Sewerage connections
x Average tariff for wastewater treatment	Market/political	Explicit regulation
= Gross operating revenue		
− Operating expenses	Operational/technical	Prequalification of operators and simple technology
= Gross internal cash generation		
− Interest payments	Financial	Fixed interest through swaps
− Amortization of loans	Financial	Long-term loan refinancing guarantees
− Income taxes	Political	Explicit contracts
− Complementary investments	Construction	Hiring of qualified contractors
− Dividends paid to investors	Political/transfer	Guarantees of repatriation
= Surplus for concessionaire/investors		

siderably by establishing a transparent and rational legislative and regulatory framework. Tariffs should cover both investment and operating costs as well as compensate sponsors adequately for assuming risks. The risk that consumers will not be willing to pay the higher charges always remains, of course. As a rule, however, the concessionaire will sign a contract with the municipality and will then assume municipal risk. This municipal risk can be mitigated through the establishment of escrow accounts that will serve as a buffer for payments to the concessionaire in case the municipality's capacity to pay slips.

Third, the risks of unexpectedly high operating costs or effluent standards that do not meet the contract can be reduced in several ways. For example, the risk that operating costs will be unexpectedly high can be reduced by requiring the use of simple or well-tried technologies rather than accepting experimental or untried ones. The risk that contractual effluent standards will not be met can be reduced by requiring operators to be prequalified.

Fourth, financial risks can often be reduced by using risk management instruments such as interest swaps. However, such financial instruments can become prohibitively expensive in high-risk countries with poorly developed financial markets. Fifth, contracts should be explicit about the income tax obligations of investors and concessionaires in order to avoid unexpected taxation. Sixth, the substantial construction risk can partially be controlled through careful pre- and post-qualification in order to ensure that only experienced contractors are used.

Allocation of Risks

After risks have been reduced through a series of judicious measures, any remaining risks have to be allocated between the different parties on the public and private sides of the BOOT contract. In a simplified form the two main sides are that of the private concessionaire and that of the government, meaning either the national government or provincial or municipal governments, as dictated by the constitution or administrative legislation of the country. Table 4.5 suggests ways to allocate risks following the principle of assigning risk to the party best able to manage the particular kind of risk.

The (medium) risk of not having a sufficient volume of wastewater to be treated could be assigned to the concessionaire. The concessionaire, in turn, may attempt to share this risk with the government by demanding a take-or-pay arrangement in which the client pays for a given volume of wastewater treated whether it is delivered to the plant or not. The concessionaire will also typically demand a release from meeting

Table 4.5. Allocation of Risk in a Wastewater Project Cash Flow

Item	*Type of risk*	*Allocation of risk*
Volume of wastewater treated	Market	Concessionaire
x Average tariff for wastewater treatment	Market/political	Government
= Gross operating revenue		
– Operating expenses	Operational/ technical	Concessionaire
= Gross internal cash generation		
– Interest payments	Financial	Concessionaire/ lenders
– Amortization of loans	Financial	Concessionaire/ lenders
– Income taxes	Political	Government
– Complementary investments	Construction	Concessionaire
– Dividends paid to investors	Political/transfer	Investors
= Surplus for concessionaire/ investors		

the contractual effluent standards if the characteristics of the incoming wastewater are substantially different from what has been stipulated.

The (high) risk of being able to charge adequate tariffs will need to be assigned to the government. This is a risk that the private concessionaire is unable to control. After all, it is the prerogative of the government to establish and ensure that tariff legislation is implemented and adequately regulated. The concessionaire should assume the (lower) risk that the client, often a municipality, will not pay the billings. However, in practice the concessionaire will often seek to pass this risk along to the central government because the payments risk in developing countries is high given the low and unreliable revenue base of many municipalities.

The fact that the government needs to guarantee the policy and implementation of the tariffs charged does not mean that it guarantees a certain level of revenue. The concessionaire should still be responsible for the commercial risk of not being able to capture a sufficient volume of wastewater to treat and for the risk that it will not be able to collect the corresponding charges. In practice, investors and operators often seek to transform the government guarantee of a tariff policy into a de facto government guarantee of a minimum level of revenue.

The (medium) risk of controlling the level of operating costs should be assigned to the concessionaire, which possesses superior experience in managing this risk. In turn, the concessionaire may involve, as part of a consortium of concessionaires or through subcontracting, an experienced operator in order to pass on the technical operating risk. The risk of receiving wastewater of different characteristics than contracted will likely be passed on to the client through the BOOT contract, with stipulations that free the concessionaire from the risk of any resulting damages or the failure to meet contractual effluent standards.

The financial risks related to the level and profile of interest payments and amortization of borrowings should be borne directly by the concessionaire and indirectly by the lenders to the project. The government should not bear this risk because the prime rationale for involving the private sector under a BOOT contract is precisely to avoid using the government's limited room for extending guarantees.

The risk that changes in tax legislation will adversely affect the project's cash flow is political in nature. Only the government can manage this risk and should logically bear it. Tax legislation should be clearly spelled out in the BOOT contract in the interest of both parties.

The construction risk should clearly be borne by the BOOT concessionaire. Often, the concessionaire will pass on this risk to an experienced construction company that is contracted to build the treatment plant under a turnkey arrangement. The construction risk is substantial for water supply and sewerage projects. A review of 120 World Bank–financed water supply and wastewater projects reports that the average expected cost overrun for these projects was 25 percent (World Bank 1992). These projects were implemented by public water and sewerage agencies, for the most part with private contractors. The public sector's poor record of controlling construction risk is a major reason in favor of switching to private BOOT contracts. Logically, the entire risk should then be borne by the private concessionaire in order to provide an incentive for timely, efficient, and within-budget construction.

Finally, the transfer risk that foreign investors or operators may not be able to change local currency to foreign currency should be borne by the government, which is in the best position to implement macroeconomic policies that will enable investors and operators to repatriate equity and profits. In turn, foreign investors could purchase insurance from bilateral and multilateral agencies (such as the World Bank Group's Multilateral Investment Guarantee Agency) against the risk that the government's macroeconomic policy will fail.

5
BOOT Examples in Latin America

This chapter describes and analyzes several BOOT projects that have been implemented or are being prepared in Latin America: two in Chile, two in Mexico, and one in Argentina (figure 5.1). In Chile, after long debates over the modality of constructing the much-needed wastewater treatment plants in Santiago, as well as in other cities, initial preparations have begun for contracting, via a BOOT contract, the first large wastewater treatment plant for Santiago. At the same time, the treatment and disposal of wastewater in Antofagasta have recently been contracted as a BOOT venture. Mexico has become active in the last couple of years in contracting BOOTs for wastewater treatment plants and, at this stage, is undoubtedly the leader in this field in Latin America. In addition to the two projects described here (Cuernavaca and Puerto Vallarta), many others are at different stages of preparation, negotiation, or implementation. In Argentina, a wastewater treatment plant for the city of Mendoza was recently completed by a BOOT contract. These projects demonstrate the feasibility of allowing the private sector to participate in water and wastewater treatment using the "new" options for financing and implementation.

Antofagasta, Chile

Antofagasta is a port city in the north of Chile, with a population of about 250,000. It is located in a desert area with little or no rainfall. Water has to be transported to the city from a distance of several hundred kilometers, and costly potable water treatment is required to remove arsenic from the water. Most of the wastewater collected from the city is disposed in the Pacific Ocean via seven short sea outfalls, which pollute the

Figure 5.1. Location of BOOT Projects in Latin America

beaches. A small amount of wastewater (about 120 liters per second) has been treated in an old activated-sludge plant, and, after chlorination for disinfection, has been reused for industrial needs in the vicinity of the plant and, after pumping to an elevated storage tank, also for crop irrigation some 10 kilometers from the plant. The wastewater treatment plant was operated by ESSAN S.A., the public company in charge of water supply and sewage disposal in the region, whereas the pumping station, storage tank, and distribution system were operated by the farmers' association. The farmers paid only for the power required to pump the wastewater. The wastewater treatment plant was poorly maintained, and only one of the two treatment modules was in operation lately

Following a bid issued by ESSAN, a new wastewater disposal and reuse system was contracted by BOOT with an Anglo-Chilean consortium (BAYESA—Biwater Aguas y Ecología S.A.). The system consists of pumping stations and collectors, a pretreatment plant to remove large solids, grit, oil, and grease, and a single, long sea outfall. Construction of the system should be completed by the end of 1997. BAYESA will operate and maintain the facilities during a period of 30 years. BAYESA will also own the facilities for the first 20 years of the contract (until they are fully depreciated in accordance with Chilean accounting practice), when they will be handed over to ESSAN. The BOOT contract also includes rehabilitation and operation of the existing activated-sludge plant and the effluent distribution system.

Although effluent reuse is not the main component of the system, the sale of effluent affects the financial feasibility of the project. Financial evaluations showed that the long-run price of the treated effluent delivered at the treatment plant would be much higher than the current price. The existing agricultural consumers of treated effluent initially received a discount of 44 percent on the long-run cost, which was to be reduced gradually every four months until the end of 1996, when all users would begin paying the full cost. The increase in cost was intended to coincide with improvements in service, which was not reliable in the early months of operation. Meters were also provided free of charge to agricultural consumers. In contrast, industrial consumers paid the full price of the effluent from the beginning, including the cost of installing the connection and a meter. Starting in 1997, when all consumers are paying the full cost and the main investments are complete, BAYESA will begin transferring part of the payments received to ESSAN.

Santiago, Chile

A total flow of about 15 cubic meters per second of wastewater produced by about 5 million people living in the Santiago metropolitan area is collected by an extensive sewerage network covering more than 7,000 kilometers of pipes and discharged virtually without treatment into three watercourses crossing or bordering the metropolitan area. These watercourses feed numerous canals that supply irrigation water to various areas totaling about 130,000 hectares, on which a variety of crops are grown all year round, including high-value vegetables for fresh consumption and fruits for export. In summer, wastewater is the only source of irrigation water in some of these areas.

indexed to inflation. At the end of the 17-year period, the facility will be transferred to SEAPAL free of charge.

The plant was designed to be constructed in two phases: in the first and completed phase the capacity of the plant is 750 liters per second, and in the second stage (to be constructed 10 years later) the capacity will be increased to 1,000 liters per second. The cost of the first stage was about $33 million in 1993, and the additional cost of the second stage will be an estimated $5 million. Financing for the first phase of the project was provided by equity from Biwater and loans from the government-owned BANOBRAS, Biwater, and the International Finance Corporation, which provided $5 million as senior debt and another $2 million as subordinated debt.

The Puerto Vallarta plant illustrates many of the benefits but also the market, operator, and financial risks of BOOT contracts. The plant was inaugurated in February 1995, a few months after the serious Mexican macroeconomic "tequila" crisis in December 1994.

The market risks have become very much a reality because the plant is receiving an average wastewater flow of 450 liters per second, which is well below the 750 liters per second that could be treated. This represents a loss of revenue for the BOOT contractor. At the same time, the Puerto Vallarta municipality has continued to operate another wastewater treatment plant, Norte I, that existed when the Biwater plant was contracted. The capacity of Norte I is about 175 liters per second, or less than the excess capacity of the Biwater plant (Norte II).

In addition, many of the hotels and condominium buildings catering to tourists were equipped with small wastewater treatment plants when the Biwater plant was contracted. These plants are under no obligation to close, although they do not produce effluents of the high standards that the Biwater plant does. This represents a second unrealized market for the Biwater plant that might develop in the future.

A third source of unrealized revenue for the Biwater plant is represented by those areas in Puerto Vallarta and neighboring Nayarit state that are not connected to sewers or do not have collectors that could carry wastewater to the Biwater plant. The reduced public investments in the aftermath of the Mexican balance-of-payments crisis in December 1994 have so far prevented the necessary sewerage systems from being built.

The BOOT contractor, CTAPV, receives a payment per cubic meter of wastewater treated. This tariff was negotiated when the contract was signed and contains an indexation formula that automatically increases the tariff as soon as the monthly change in the price index exceeds a certain level. The contractual tariff level has been honored in spite of the macroeconomic difficulties since the December 1994 crisis.

In order to guarantee payment, a credit line, guaranteed by the state of Jalisco, was established with the fiduciary agent, the government-owned BANOBRAS. The credit line provides for payments to Biwater in cases where SEAPAL might suffer liquidity problems. It is uncertain to what extent SEAPAL is able to pass on to its own consumers the wastewater treatment fee that it pays to Biwater.

The financial risks to the operator materialized when the plant was still under construction. The fact that the Mexican peso fell from a rate of Mex$3.1 per U.S. dollar to Mex$8.0 per U.S. dollar (November 1, 1996) in the course of about two years obviously reduced the value of the equity and increased the debt service on any foreign borrowings.

The BOOT plant has produced effluent of a quality that has consistently exceeded the contractual standards. The plant has even served as a demonstration plant for visitors from other wastewater treatment plants in Mexico. To this extent, the plant has amply fulfilled the objective of bringing well-tested plant design and operation to Mexico.

Mendoza, Argentina

The greater Mendoza metropolitan area has a total population of 700,000, which is estimated to grow to 1 million by 2010. Sewerage coverage is projected to increase from 75 percent at present to 95 percent by 2010. Mendoza is located in an arid region in the foothills of the Andes in the western part of Argentina. The city's wastewaters have by tradition been used indirectly for irrigation.

Two wastewater treatment plants are in operation: Campo Espejo, a primary treatment plant with an average flow of 1.6 cubic meters per second and serving a population of about 310,000, and Paramillo, a lagoon treatment plant treating an average flow of 1.2 cubic meters per second.

To upgrade the quality of the effluent, the public water company (Obras Sanitarias de Mendoza) recently bid and awarded a 20-year BOOT contract to operate and maintain the existing installations, as well as to design, construct, and operate a lagoon system consisting of 12 modules, each including three lagoons in series (two facultative and one polishing), which should produce an effluent of a quality acceptable for unrestricted irrigation according to World Health Organization standards. The lagoons cover a total area of about 320 hectares.

The treated effluent will be conveyed to a 1,900-hectare irrigation area, where the quality of the agricultural produce and the health of the agricultural workers will be monitored. The possibility of charging farmers part of the cost of treatment is being considered. About one-quarter of the irrigated area is devoted to the production of grapes, another quarter to the cultivation of tomatoes and squash, and the remaining area to the cultivation of alfalfa, artichokes, garlic, peaches, pears, and poplar biomass.

The bidding process was straight-forward. Bidding documents were drafted and reviewed by the Procurement Committee of the Province of Mendoza under the Provincial Concession Law no. 5507/90. The bidding documents specified criteria for the quality of effluent, such as a maximum of 1,000 coliform per 100 milliliters, a maximum of one helminth egg per liter, removal of at least 30 percent of biochemical oxygen demand, and removal of at least 70 percent of suspended solids. The bidding documents defined a certain level of fines for failure to produce an effluent of the standard specified. The Province of Mendoza guaranteed a minimum wastewater flow of 3 million cubic meters per month. The selection criterion used was the wastewater treatment charge per cubic meter demanded by the BOOT bidders.

Five contractors submitted bids. The bid wastewater treatment charges varied from a $0.05 to $0.11 per cubic meter plus value added tax. The negotiated contract price was below $0.05 per cubic meter treated. Subsequently, the first phase of the oxidation ponds was constructed and is now in operation.

Appendix. Conventional Wastewater Treatment Processes

A brief review of sewage treatment history indicates that many of the so-called new developments are not new and have been known for a long time. Sewage has been used to irrigate land since early on. The First Sewage Commission of England and Wales recommended in 1857 that municipal sewage be applied continuously to the land in order to avoid pollution of rivers. Another Royal Sewage Commission reiterated the recommendation in 1884 that sewage be applied to the land before it is discharged into a stream. However, it was also realized that applying sewage to land requires large areas, which makes land application impractical for big cities.

In 1884, before biological treatment was discovered, the Royal Sewage Commission recommended chemical precipitation to remove organic matter from sewage. This was long before the recent interest in using chemical precipitation to remove phosphorus from effluents in order to control eutrophication of lakes. Similarly, discovery of the "fill-and-draw" activated-sludge process at the beginning of the twentieth century preceded that of the conventional, continuous flow activated-sludge process. Today there is renewed interest in a rather similar process (sequencing batch reactors) for certain applications.

The major man-made, intensive wastewater treatment processes in use today were developed at the beginning of this century, when population growth and industrialization of large cities in Europe and the United States started to limit the application of natural treatment methods that were in use in the previous century.

No historic note on sewage treatment would be complete without referring to the establishment in 1915 of the Royal Commission's standard of 20/30 for the disposal of sewage effluent into rivers (biochemical oxygen demand of 20 milligrams per liter and suspended solids of 30 milligrams per liter). This standard remains largely valid today, despite the need to improve quality.

Preliminary and Primary Treatment

Preliminary or pretreatment is the first step in most wastewater treatment schemes and aims at removing coarse solids. It includes as a minimum bar screens and nonaerated or aerated grit chambers. Primary treatment consists in most cases of primary sedimentation, which is probably the most widely used unit in wastewater treatment. In some cases—before secondary treatment facilities are built—it is used for a certain period of time as the only treatment prior to disposal. In most cases, primary treatment precedes biological treatment and is aimed at reducing suspended solids and organic load. Typically, primary sedimentation can remove 50 to 60 percent of the influent suspended solids and 30 to 40 percent of the influent biochemical oxygen demand.

Primary sedimentation occurs simply because solids reaching the primary sedimentation tanks are susceptible to natural flocculation, which is aided by the motion of the fluid within the tanks. The main factors affecting the performance of primary sedimentation tanks are hydraulic surface loading, or overflow rates, and hydraulic detention time. Primary treatment removes settleable solids, floating materials, oil, and grease and reduces the organic load on the subsequent treatment units.

When lagoons are used for biological treatment, neither preliminary nor primary treatment is essential, because the first lagoons can fulfill their functions and act as a deposit for coarse suspended solids. In some modifications of the activated-sludge process, such as extended aeration, primary sedimentation is not required prior to biological treatment.

The main problem of primary sedimentation is that only relatively large particles (larger than 0.01 millimeter in diameter), which include gravel, coarse and fine sand, and silt, can settle within the practical range of detention times provided by these tanks (around two hours). Particles such as colloids of smaller size and bacteria (0.001 millimeter in diameter) take much longer to settle—hours, days, or even years. Such smaller-size particles can be removed only if flocculating chemicals are added to the primary sedimentation tanks. This process—referred to as chemically assisted primary sedimentation—is gaining renewed popularity.

Secondary Biological Treatment

Biological treatment, which is the nucleus of almost any conventional wastewater treatment plant, is aimed at removing or stabilizing, by means of microorganisms, the colloidal and soluble organic matter present in wastewater. The process requires adequate environmental conditions for the growth of microorganisms, such as pH, temperature, oxygen (for aerobic bacteria) or lack of oxygen (for anaerobic bacteria), and nutrients. Aerobic biological treatment processes are essentially of two types:

- Attached-growth processes, such as trickling filters, where the bacteria performing the treatment are attached to rock or plastic media, or rotating biological contactors, where the bacteria grow on the surface of a plastic rotating disk
- Suspended-growth processes, such as activated sludge, where the bacteria are suspended in the wastewater.

The most widely used biological treatment is the activated-sludge process, presumably because it can produce high-quality secondary effluent. It is usually preceded by primary sedimentation, although this may not be necessary in some of its variations. The activated-sludge process consists of an aeration tank, where wastewater and recirculated sludge are mixed and aerated to form a thick liquid biomass (known as mixed liquor), and a secondary sedimentation tank, where this biomass undergoes gravity separation, in which the clear liquid is separated from the sludge solids. The aeration tank must provide sufficient retention time for the bacteria to grow. Air or oxygen-enriched air provided by a suitable source must be introduced by adequate equipment to maintain aerobic conditions in the aeration tank. Mixing equipment is also necessary to maintain aerobic conditions in the entire aeration tank. A certain amount of excess activated sludge must be continuously wasted from the system.

A successful activated-sludge plant is one in which both the aeration tank and the secondary sedimentation tank perform their tasks. This happens only when the colloidal and dissolved organic matter is converted into a biomass that settles easily by gravity. In many instances, however, the biomass does not settle well because of the so-called bulking-sludge phenomenon, which is caused by uncontrolled growth of filamentous-type bacteria.

Along with its many advantages, such as the relatively limited area required by large plants, activated sludge is a complex process that requires careful and knowledgeable operation, can be upset by industrial shock loads, and does not improve the bacteriological quality of the effluent, unless heavy chlorination (with its disadvantages) is provided to the final effluent.

One of the complexities of the activated-sludge process, which is an additional cause of confusion for the design engineer, even after the decision has been made to select activated sludge among all the alternative biological processes available, is the great number of alternative processes and modifications available:

Process	*Modifications*
Conventional	
Plug-flow	Contact stabilization
Tapered aeration	Oxidation ditch
Step-feed aeration	Extended aeration
	Sequencing batch reactor
	Pure-oxygen
Advanced	
Nitrification	
Nitrification-denitrification	
Nitrification-denitrification and phosphorus removal	

Anaerobic Treatment

Anaerobic biological treatment, which has been traditionally used for sludge treatment as well as for certain high-strength organic industrial wastes, has been used lately for municipal wastes, too. Anaerobic treatment has some advantages, along with disadvantages, when compared with aerobic treatment. The advantages are:

- It allows high organic loading rates and thus reduces the amount of area required (this is particularly important in the case of anaerobic ponds compared with aerobic or facultative ponds)
- It does not require costly oxygen
- It produces less sludge, because only about 5–10 percent of the organic carbon is converted to biomass (about 50 percent in aerobic processes)
- It produces a useful gas (methane), which can be burned on-site to provide heat for digesters or to generate energy for use within the plant.

The disadvantages of anaerobic treatment are:

- Anaerobic digestion is a slower process than aerobic oxidation
- It is more sensitive to upsets by toxic substances
- Its unstable end products may generate bad odors
- A long start-up period may be needed to acclimate the anaerobic bacterial population
- It requires energy for heating, mainly in cold climates.

Anaerobic treatment cannot completely stabilize organic matter and must be followed by aerobic treatment if a high-quality effluent is desired. The combination of anaerobic and aerobic biological treatment has the advantage of being able to deal with a wide variety of organic compounds, some of which are degradable by aerobic bacteria and others by anaerobic bacteria.

The main operational difficulty of anaerobic reactors is due to the fact that the anaerobic process is a two-stage process, each stage being carried out by a different group of bacteria, with the second-stage bacteria being more sensitive than the first to environmental conditions such as pH. In the first stage, acid-forming or nonmethanogenic bacteria convert the organic matter present in sewage to organic acids, whereas in the second stage, methane-forming bacteria or methanogens convert the organic acids to methane gas and carbon dioxide. For efficient performance, the methanogens require a pH in the range 6.5–7.5, and they cannot develop at all below a pH of 6.2. However, if too many acids are produced by the acid-forming bacteria, which develop and multiply easily, the result is a low pH, which may impede the production of methanogens. In the presence of high concentrations of sulfates, the methanogens also compete with the sulfur-reducing bacteria. The main consequences of such a situation are the appearance of unpleasant odors and a reduction in the efficiency of the anaerobic process. Although the problem can be corrected by adding lime or other chemicals to raise the pH, it is preferable to prevent it by controlling the pH and the volatile acids concentrations.

The anaerobic process usually requires artificial heating, because the optimum temperature for both groups of bacteria (nonmethanogens and methanogens) is at least 35 degrees Celsius.

Although the complete-mix process is still the most widely used anaerobic digestion process, mainly for primary or combined sludges, other anaerobic treatment processes have been used for industrial (concentrated) as well as municipal (diluted) wastewaters. These include attached-growth processes, such as the anaerobic filter (the anaerobic equivalent of the trickling filter) and the upflow packed bed, and suspended-growth processes, such as the anaerobic contact (the anaerobic equivalent of the activated sludge) and the upflow anaerobic sludgeblanket or UASB process. The latter has been used in several plants in Brazil and Colombia.

Advanced Treatment

Advanced treatment includes processes required to remove various contaminants remaining in the effluent after primary and secondary biological treatment.

Phosphorus Removal

When effluents are disposed into lakes or reservoirs, nutrients such as nitrogen (N) and phosphorus (P) are of concern, because they stimulate the growth of algae, causing eutrophication of lakes and deterioration of water quality. Phosphorus, which is the only nutrient not readily available from the atmosphere or the natural water supply, is the limiting factor—it was found to correlate well with the concentration of chlorophyll (algae).

Postprecipitation is the conventional method of removing phosphorus, that is, tertiary chemical treatment following biological treatment, using alum (aluminum sulfate), iron salts (mainly ferric chloride), or lime. Less conventional methods of removing phosphorus are preprecipitation or chemically enhanced primary sedimentation (prior to biological treatment) and coprecipitation or simultaneous precipitation (the addition of chemicals for removing phosphorus in the biological process itself).

Lime Treatment

Lime treatment is perhaps the best example of an old wastewater treatment process, which was abandoned in favor of biological treatment processes and then readopted as an advanced treatment to remove phosphorus and heavy metals and toxic substances. A clear distinction should be made between low-lime treatment that raises pH to 9.0–9.5 and high-lime treatment that raises pH to 11.0–11.5. Low-lime treatment can remove phosphorus, suspended solids, and some heavy metals such as lead and zinc that form low-solubility carbonates. High-lime treatment can remove phosphorus, suspended solids (including algae), organics, calcium and magnesium hardness, bacteria, viruses, and a variety of metals and toxic elements that form low-solubility hydroxides such as cadmium, copper, iron, manganese, lead, zinc, boron, and fluorine.

High-lime treatment thus has the capability of softening as well as disinfecting water. In addition, at high pH, most of the ammonia present in wastewater is converted to free ammonia (NH_3), which can then be removed by air stripping that takes place in ammonia stripping towers or ammonia stripping ponds (nonaerated or aerated). High-lime treatment usually requires high dosages of lime to raise the pH above 11. The process is particularly efficient if sufficient magnesium is present in the wastewater to precipitate as magnesium hydroxide at high pH values. To raise the pH, either quicklime (CaO) or hydrated lime $Ca(OH)_2$ can be used. Because of the large amounts of lime added in the process, high-lime treatment produces large quantities of sludge. The lime sludge, however, is more readily dewatered than other chemical sludges such as alum sludge.

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