Lessons from Lake Nakuru, Kenya and the Bhoj Wetland, India

Implementing Sewerage and Sewage Treatment Schemes in Developing Countries

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1. Introduction

Pollution of lakes from discharge of untreated or partially treated sewage is a common problem in many lakes around the world, especially in developing countries. It is particularly a major problem in small urban lakes which have less absorptive capacity for the large amounts of wastes generated in the urban areas, or in coastal areas of large lakes with settlements. Domestic sewage contains pathogens which contaminate lake water resulting in outbreaks of waterborne diseases. Input of nutrients contained in sewage can result in eutrophication of lakes, and input of organic matter results in reduced dissolved oxygen concentration. If sewage contains industrial effluents, toxic contamination by persistent organic pollutants and heavy metals can also occur. These problems result not only in the impairment of human use values of lakes but also degradation of the entire lake ecosystem.

Installation of sewerage systems in lake basins is one of the measures taken to address the above problems. However, in most cases, the justification for sewerage systems is often for protection of public health rather than for protection of lakes or environment in general (see Box 1). It is estimated that more than 2.6 billion people (corresponding to over 40% of the global population) do not have access to basic sanitation, and more than one billion people do not have access to safe drinking water (WHO and UNICEF 2004). Most of the people without access to sanitation and safe water are to be found in developing countries. The Millennium Development Goals (MDGs) have set to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. While good progress is being made to meet the drinking water target, progress in sanitation lags behind.

The slow progress in sanitation provision is not unique to developing countries only. Experience in developed countries shows that, in these countries too, it took a long time to achieve the current high levels of sewerage coverage. This is attributed to, among others, the low priority traditionally given to sanitation and the relatively high cost of providing sanitation compared to water supply. Sewerage provision in developing countries is even a much bigger task, given the high poverty and governance problems that generally prevail in these countries. Under this background, this paper reviews the challenges of implementing sewerage systems in developing countries with a view to drawing lessons for the future. The paper focuses on sewerage systems for domestic wastewater in urban areas and is based on case studies of two typical urban lakes in developing countries, namely the Bhoj Wetland in India and Lake Nakuru in Kenya.

Box 1. Technological Intervention for Lake Basin Management are Difficult to Promote on Environmental Grounds Alone

- Investments in technologies that support lake basin management come in several forms. Some technological interventions such as primary or secondary sewage treatment or on-site sanitation (such as pit latrines, soakaways and septic tanks) are constructed for public health purposes for communities along the shoreline or in the basin but may have significant supplementary environmental benefits.

- Other technologies such as tertiary treatment for removing nutrients from sewage may be designed specifically to improve the lake water environment.

- Justifying the introduction of technological interventions strictly for the purpose of lake environment protection is generally quite difficult unless the long-term resource values of the protected environment are properly accounted for in decision making. The long-term view in policy making is critical in appropriately introducing protective technological interventions.

Source: ILEC 2005

2. Key Considerations

2.1 Wastewater Treatment Technology

Sewage treatment may be classified into four categories, namely, on-site treatment, conventional treatment, advanced (tertiary) treatment, and treatment by natural systems (Box 1). These methods are briefly introduced below.

2.1.1 On-site treatment

On-site treatment involves treating wastewater at the point of generation. It consists of individual household disposal systems such as latrines and septic tanks. This is the method commonly used in rural and many urban areas in developing countries because it is less expensive. However, this method has the potential to contaminate ground water through infiltration or contaminate surface water through overflow and subsequent runoff in stormwater.

In recent years there has been growing interest in technological development of ecological sanitation (ECOSAN) systems. These systems encourage resource conservation (such as dry toils that save water and produce organic compost) and also incorporate resource recovery and reuse (such as separation of urine and feces for extraction of phosphorus). It is expected that ECOSAN will find wide application in low-cost sanitation projects in developing countries in future.

2.1.2 Conventional Wastewater Treatment

Conventional wastewater treatment involves collection of wastewater from various points of generation, its transportation and then treatment at a central location. Conventional treatment consists of primary and secondary treatment. Primary treatment employs physical operations to remove large floating and settleable materials from sewage. On the other hand, in secondary treatment, biological and chemical processes are used to remove organic matter and pathogens. However, as discussed below (see Table 1), capital and running costs of conventional wastewater treatment systems are very high and often beyond the means of developing countries. In many cases, conventional systems in developed countries are externally funded by donors and development agencies.

2.1.3 Advanced Wastewater Treatment

Advanced wastewater treatment is an additional process to conventional wastewater treatment that is carried out after secondary treatment. Advanced treatment removes nutrients that are not significantly removed by secondary treatment. Removal of nutrients helps to prevent eutrophication of surface water bodies due to increased nutrient

Table 1. Cost Range for On-Site and Sewered (Conventional Treatment) Options

Economy (GNI/capita)[1]	Option	Capital Cost		Capital + O&M	
		US$/capita	%[4]	USD/capita/ year	%[6]
Low-Income Economies (<USD765)	On-site sanitation	10 - 100	>7.2	3 - 10	>0.8
	Treatment plant[2]	20 - 80	>6.5	5 - 15	>1.3
	Sewer + treatment[2]	200 - 400	>39.2	10 - 40	>3.3
Middle-Income and Transitional Economies (USD765-9,385)	Treatment plant	60 - 80[2]	0.7 - 9.2	-	-
		30 - 50[3]	0.4 - 5.2	-	-
	Sewer + treatment	300 - 500[3]	4.3 - 52.3	30 - 60[5]	0.5 -5.9
Industrialized Countries (>USD9,385)	Treatment plant	150 - 300[2]	<2.4	-	-
		100 - 200[3]	<1.6	-	-
	Sewer + treatment	-	-	100 - 150[5]	<1.3

- Not available

O&M Operation and maintenance

GNI Gross National Income

Notes

1 The original classification of economies in UNEP (2001) did not specify GNI data. In this paper, the GNI values are assumed to correspond to those provided by the World Bank according to 2006 GNI data.

2 For primary plus secondary treatment, including land purchase and simple sludge treatment, for a capacity of 30,000-40,000 persons. Lower values pertain to low-cost options, such as waste stabilization ponds; higher values pertain to mechanized treatment, such as oxidation ditches and activated sludge plants.

3 For plant capacity for 100,000 - 250,000 persons.

4 Capital cost in USD/capita as a percentage of GNI/capita. The average of the lower and upper limits of cost is assumed.

5 For industrialized countries, this includes tertiary treatment and full sludge treatment; for other countries, this includes basic secondary treatment.

6 Total cost in USD/capita/year as a percentage of GNI/capita. The average of the lower and upper limits of cost is assumed.

Source: Adopted from UNEP 2001

input. However, advanced treatment is costly and is mainly applied in developed countries.

2.1.4 Treatment by Natural Systems

Treatment by natural systems (also referred to as land treatment) uses natural systems such as land, vegetation and wetlands to purify wastewater. Because the method relies on natural processes which are usually slow, vast areas of land are required. The method is therefore mostly applicable in areas where the cost of land is low. Properly designed and maintained, this method can produce effluent quality comparable to or even of much higher quality than advanced wastewater treatment.

2.2 Cost of Wastewater Treatment

The cost of wastewater treatment varies widely depending on the type of treatment and local circumstances. Table 1 provides indicative costs for different wastewater treatment options. In Low-Income countries, the capital cost per capita for conventional wastewater treatment systems with sewers corresponds to more than 39% of the Gross National Income (GNI) per capita. Such cost is prohibitive and therefore Low-Income Economies may only be able to afford on-site systems or treatment plants without sewer lines. Some rich cities in Low-Income Economies could afford the "Capital + O&M (Operation and Maintenance)" costs for sewered systems on a yearly basis (Table 1). However, even for these cities, it would be unrealistic to expect them to raise the required capital costs without external financial assistance.

Similarly, some countries in Middle Income and Transitional Economies may be able to afford the "Capital + O&M" costs on an annual basis. However, they may not be able to bear the capital costs and therefore some form of financial assistance by donors is needed. The foregoing discussion illustrates the important fact that because of the high cost of wastewater treatment systems the choice of the appropriate system for a given situation should be done with due consideration of affordability to ensure long term sustainability of the system.

2.3 Water Quality Criteria, Objectives and Standards

Water quality criteria, objectives, and standards are important in water quality management because they provide a basis for regulation and monitoring progress towards achieving set targets. Table 2 provides definitions of these terms which follow a common approach used at lake basins around the world.

Establishment and enforcement of effluent discharge standards are particularly critical to the proper operation of STPs in developing countries. In many developing countries, it is often the case that industrial effluents are discharged into the sewerage system without treatment or with only preliminary treatment. These effluents may contain toxic compounds that may negatively affect the biological processes at sewage treatment plant (STPs). In addition, STPs are not normally designed to remove toxic compounds. Therefore the toxic compounds pass through the treatment process without removal and are eventually discharged to the environment causing pollution. When setting water quality criteria, objectives and standards, realistic targets that are achievable under the prevailing local socio-economic and technological conditions should be considered. For example, it may be desirable to set less stringent water quality standards that are achievable rather than stringent standards that are not achievable. The less stringent standards may be tightened as the economic, technological and institutional capacity to comply with higher standards increases.

3. Case Studies

3.1 Bhoj Wetland

3.1.1 Introduction

The Bhoj Wetland (also called Lake Bhopal) is located in Bhopal, the capital of Madhya Pradesh State in India. The lake consists of two man-made lakes, the Upper Lake and the Lower Lake (Figure 1). The Upper Lake has a surface area of 36 km^2 and a catchment area of 361 km^2 while the corresponding figures for the Lower Lake are 1.29 km^2 and

Table 2. Definitions Related to Water Quality Management

Term	Definition
Water-quality criterion (synonym: water quality guideline)	A numerical concentration or descriptive statement recommended to support and maintain a designated water use. Water-quality criteria are developed by scientists and provide basic scientific information about the effects of water pollutants on a specific use (e.g. drinking water) or function (e.g. support of aquatic life).
Water-quality objective (synonym: water quality goal or target)	A numerical concentration or descriptive statement which has been established to support and to protect the designated uses of water at a specific site, river basin or part(s) thereof. The drawing-up of water-quality objectives is not a scientific task but rather a political process that requires a critical assessment of set priorities, present and future water uses, forecasts of industrial and agricultural development, and other socioeconomic factors.
Water-quality standard	A numerical concentration, descriptive statement or objective that is recognized in regulations or enforceable environmental law applicable at the international, trans-boundary, national and/or local levels.

Source: Adapted from Helmer and Hespanhol (1997) and UN/ECE (2000)

Figure 1. Bhoj Wetland Basin (ILEC 2005)

9.6 km², respectively. The population in the basin of the two lakes is estimated at 500,000. The Western part of Bhopal City (about 18% of the city area) lies in the catchment area of the lakes. The Upper Lake provides more than 40% of the drinking water supply for an estimated population of 1.8 million in Bhopal City. The lakes have been designated as a Ramsar site. The environmental condition of Lake Bhopal has deteriorated over the past years because of inflow of point and non-point source pollution such as sewage and solid waste from the urban area and silt and nutrients from the rural catchment, and encroachment on the lakeshore. These stresses have resulted in severe eutrophication, water hyacinth infestation, heavy metal pollution, sedimentation, and solid waste pollution.

The population of Bhopal City grew rapidly from 75,000 in 1941 to 384,000 in 1971 and to 1,433,000 in 2001 (BMC undated). As the population grew, the city expanded and many parts of the lake shoreline were enchroached upon. Domestic wastewater from the city was discharged directly into the lakes without any treatment, causing severe degredation of the water water quality and threatening the important source of water for the city. To address this situation, the State Government of Madhya Pradesh (GOMP), with support from the Indian Government, initiated measures to conserve the lakes in the late 1980s. However, GOMP did not have adequate funds to undertake the needed conservation activities. The Japanese Government therefore provided funds through an Official Development Assistance (ODA) loan to implement a lake conservation project called Lake Bhopal Conservation and Managemnet Project, LBCMP. One of the major components of LBCMP was rehabilitation and expansion of the sewerage system in Bhopal City.

3.1.2 Lake Bhopal Conservation and Management Project

LBCMP was implemented between 1995 - 2004 to promote improvement of water quality and overall environmental conditions of the Bhoj Wetland. The project had six major components as shown in Table 3. The following discussion section will focus on the sewage component. Details of the entire project are available in Kodarkar and Mukerjee (2005) and Nakamura *et al*. (2008).

Table 3. Outline of Lake Bhopal Conservation and Management Project

Item	Details
Total Project Cost	7,706 million Yen
Funding Agency	JBIC
Loan or Grant	Loan
Terms and Conditions	Interest rate: 2.6% Repayment period: 30 years (10 years grace period) General untied
Project Duration	February 1995 - June 2004
Major Project Components	1) Sewerage scheme 2) Desilting and dredging of the lakes 3) Catchment area treatment (afforestation, gabions and silt traps) 4) Management of shoreline and fringe area (construction of link road, solid waste management, relocation of washermen (dhobis) from lakeshore) 5) Improvement and management of water quality (deweeding, biological control of weeds, water quality monitoring and installation of aerators) 6) Awareness campaigns, Establishment of Interpretation Center, Promotion of organic farming

Source: Kodarkar and Mukerjee 2005; Nakamura et al. 2008

The sewerage component was the largest in terms of funding among the six components of LBCMP. Major outputs of the sewerage component include: 1) Construction of 4 STPs with capacity 53,990 m3/d, 2) Rehabilitation of 1 STP of capacity 4,540 m3, 3) Construction and rehabilitation of sewage pumping houses, 4) Laying of 85 km sewer pipes, and 5) Construction of diversion systems for open drains. The STPs use waste stabilization pond process.

Table 4 summarizes the situation in the LBCMP area before and after implementation of the project. The sewerage system in Bhopal consists mainly of drainage through open canals (nallahs). Before LBCMP was implemented only 4,000 m^3/d treatment capacity was available at the existing STPs. This capacity was by far much less than the amount of sewage generated in the project area. Therefore most of the sewage was directly being discharged to the lakes without treatment. LBCMP significantly increased the capacity of the STPs to 58,530 m^3/d. However, at present, only about 15,000 m^3/d of sewage (25% of the treatment capacity) reaches the STPs indicating that the STPs are underutilized. One reason for this is because the rate of connection to the piped sewer network is still very low. Most of the sewage is drained through open canals which are diverted to sewage pumping houses (SPHs) and then pumped to STPs for treatment. It is estimated that a significant amount of untreated sewage still flows to the lake. Even though the STPs are currently operating below their capacity, sewage flow to the STPs is projected to increase in future and surpass capacity of the STPs, necessitating need for increase in capacity of the STPs.

The STPs use waste stabilization pond process and are achieving the intended effluent quality. The major problem noted is limited budget allocation for operation and maintenance (O&M) of the sewerage facilities.

3.2 Lake Nakuru

3.2.1 Introduction

Lake Nakuru is a small (surface area of 30 km^2, catchment area of 1,800 km^2) shallow alkaline-saline lake in the Kenyan Rift Valley (Figure 2) that is world famous for its huge congregations of lesser flamingos. The lake and the area surrounding it comprise the Lake Nakuru National

Figure 2. Lake Nakuru Basin (ILEC 2005)

Park (LNNP), a protected National Park. LNNP is the second most important National Park in Kenya in terms of earnings from tourism. LNNP is a UNESCO designated World Heritage site, Kenya's first Ramsar site, and also Africa's first bird sanctuary (Odada *et al*. 2005). The lesser flamingos are a major tourist attraction, contributing significantly to the regional and national economy. In recent years, there has been concern over sporadic lesser flamingo mortalities in Lake Nakuru. The flamingo deaths have been attributed to poisoning by heavy metals, pesticides, and algal toxins, bacterial infection, and malnutrition (Ndetei and Muhandiki 2005). Major concerns in the lake basin include water abstractions, deforestation, cultivation and urbanization.

Nakuru, which is located just a few km to the north of the lake, is currently the fourth largest town in Kenya and the headquarters of the Rift Valley Province. The population

Table 4. Outline of Sewerage System in LBCMP Area

Item	Before Project (1994)	After Project (2007)
Estimated population in project area[1]	233,000	360,000
Estimated population served in project area (%)	10	90[2])
Estimated amount of sewage treated at STPs (m^3/d)	4,000	15,000
Installed treatment capacity (m^3/d)	4,000	58,530
Rate of STP facility utilization in project area (%)	100	25

1 Project area covers about 18% of the Bhopal Municipality area

2 About 15 - 20% are by house connections to piped sewers, the rest by diversion from open drains

Source: Public Health Engineering Department, GOMP of Nakuru has increased six times since Kenya's independence in 1963, from 38,000 in 1962 to 231,000 in 1999 (JBIC 2002). In line with population increase, the Nakuru Town has been expanding in size over the years as illustrated in Figure 2. The rapid population growth has put tremendous pressure on urban infrastructure, particularly water supply and sanitation.

3.2.2 Water Supply and Sewerage Projects in Nakuru

The Greater Nakuru Water Supply Project, GNWSP (referred to below as the water project) and the Nakuru Sewerage Works Rehabilitation and Expansion Project, NSWREP (referred to below as the sewerage project) were implemented with ODA funding from the Japanese Government. Funding for the water project was a loan while that for the sewerage project was a grant (Table 5). The water supply project provided an additional 18,000 m^3/d of water while the sewerage project rehabilitated and expanded sewage works at two locations in Nakuru Municipality, increasing the sewage treatment capacity by 9,200m^3/d. The sewerage project also provided a rainwater detention pond and a water quality testing laboratory.

The water supply project was the first to be conceived and implemented. Increased water supply from would inevitably lead to increased flow of wastewater to Lake Nakuru because existing STPs were already overloaded. Therefore, during appraisal of the water project it was planned that the Kenyan side would take measures to address the increased wastewater flow. However, the Kenyan side was not able to do so and this led to concern that the water quality in Lake Nakuru would be adversely affected. In the course of implementing the water project it was therefore decided to use some of the ODA loan funds for the water project to build sewage treatment facilities. In addition, extra funds were provided by the Japanese government in form of an ODA grant for the sewerage project.

The two STPs installed in Nakuru use waste stabilization pond process with rock filter and grass plots. The sewerage situation in Lake Nakuru Basin is shown in (Table 6). The sewerage project covers about 45% of the population in Nakuru Municipality. Of the population in the sewered area, only about 40% is connected to the sewerage system. Those who are not connected use pit latrines (85%) and septic tanks (15%).

As shown in Table 6, the amount of sewage flow to the STPs is only 56% of the design capacity. This is attributed to low rate of connection to sewerage system, losses through leakages, and intermittent flow due to water rationing and shortages. One of the STPs does not discharge effluent through its drainage channel to the lake because the amount of sewage reaching the STP is very small. The effluent at the STP is lost through evaporation or leakage.

It is projected that the water demand for Nakuru Municipality will rise from the current amount about 35,000 m^3/d to 103,000 m^3/d in 2020. Likewise, the sewage flows to STPs are projected to rise from the current 9,000 m^3/d to 58,000 m^3/d in 2020 (NWCPC 1998). There will be a need to increase the capacity of the STPs to meet this projected increase in sewage flows.

The STPs achieve more than 95% reduction of BOD concentration of influent and the effluent design standard of less than 15 mg/L for BOD is met. Thus, the treatment plants are achieving expected reduction of pollution load. Table 7 shows the estimated BOD load to Lake Nakuru from domestic wastewater in Nakuru Municipality. It is

Table 5. Outline of Water Supply and Sewerage Projects in Nakuru

Item	Greater Nakuru Water Supply Project	Nakuru Sewerage Works Rehabilitation and Expansion Project
Total Project Cost	5,092 million Yen	2,804 million Yen
Funding Agency	JBIC	JICA
Loan or Grant	Loan	Grant
Terms and Conditions	Interest rate: 3.5% Repayment period: 30 years (10 years grace period) Partial untied	
Project Duration	October 1987 - October 1994	August 1994 - 1997
Major Project Components	1) Construction of new water intake, aqueduct, treatment, conveyance and distribution facilities 2) Rehabilitation of existing facilities (17,000 m3/d additional capacity)	1) Refurbishment and expansion of existing sewage treatment works (two locations with 9,200 m3/d additional capacity) 2) Construction of a new rainwater detention pond 3) Refurbishment of pumping facilities 4) Construction of a water quality testing laboratory and procurement of water quality testing equipment and materials 5) Procurement of equipment and materials for maintenance (vehicles etc.)

Source: Nakamura et al. 2001; NWCPC 1998 estimated that of the 13,100 kg/d of total BOD load generated, 6,940 kg/d BOD reaches Lake Nakuru. In other words, about 47% of the total BOD load generated is removed by the various wastewater treatment options (sewerage, pit latrine and septic tank). The low removal rate for BOD is largely because grey water from the population that uses pit latrines (74%) flows directly to Lake Nakuru without treatment. The need to provide an alternative to pit latrines is apparent.

3.3 Synthesis and Lessons Learned

In this section, the Bhoj Wetland and Lake Nakuru case studies introduced in the previous sections are synthesized to draw lessons for implementing sewerage systems in developing countries. Rather than drawing broad and generalized lessons, this section will focus on key lessons that specifically stand out in the two case studies reviewed. For the former, reference should be made to UNEP 2001 and 2004.

3.3.1 Prioritizing Sewerage Works

As mentioned in Section 1, it is often difficult to promote the introduction of sewerage systems strictly for the purpose of protecting lakes or the environment in general. Rather, in most cases, sewerage systems are installed for public health concerns. However, the Bhoj Wetland and Lake Nakuru demonstrate rare cases where protection of the lake environment seems to have been a major driving force for installation of sewerage systems. Both lakes share the characteristic of being urban lakes that are highly valued: the Bhoj Wetland being and important water source for Bhopal City and Lake Nakuru being important for tourism. In both cases, the threats to the values of the lake resources from sewage pollution were recognized and interest in lake conservation was created among decision makers and ordinary citizens. This interest influenced the decision to install sewerage systems.

In the two case studies, there was no comprehensive quantitative assessment of lake resource values (e.g. using economic techniques such as Total Economic Value, TEV). Rather, decisions seem to have been based on qualitative assessment of the values. Even though quantitative valuation is a powerful economic tool in environmental economics, given the many intangible values of lake resources, the purely qualitative approach taken in the two case studies seems to be quite reasonable. The lessons to be learned in this regard are:

- If long-term resource values of lakes are properly understood and taken into consideration in decision making, installation of sewerage works for lake basin protection can receive high priority.
- While quantitative assessment of the lake resource values may be desirable to influence decision making, even proper qualitative assessment alone may suffice.

Table 6. Outline of Sewerage System in Nakuru Municipality

Item	Amount
Population in Municipality	231,000 (100%)[2]
Estimated population in outside sewerage service area	127,700 (55%)[2]
Estimated population in sewerage service area	103,600 (45%)[2]
Estimated population connected to sewerage in service area	41,400 (40%)[3]
Estimated amount of sewage treated at STPs (m^3/d)	9,000
Installed treatment capacity (m^3/d) [1]	16,200
Rate of STP facility utilization (%)	56%

1 Existing capacity before the water and sewerage projects was 7,000 m^3/d

2 Percentage of total population in Nakuru Municipality

3 Percentage of population in sewerage service area

Source: JBIC 2002; NWCPC 1998

Table 7. Estimated BOD Load to Lake Nakuru from Domestic Wastewater in Nakuru Municipality

Area	Treatment Option	Population	BOD (kg/d)
Sewered Area	Sewerage	41,400	120
	Pit Latrine	62,200	2,400
Un-sewered Area	Septic Tank	19,200	220
	Pit Latrine	108,500	4,200
Total[1]		231,100	6,940
Total Load if there is No Treatment[2]			13,100

1 Estimated total BOD load discharged to Lake Nakuru at present

2 Corresponds to total BOD load generated in Nakuru Municipality

Source: JBIC 2002

3.3.2 *Financing Capital Costs*

Capital costs for sewerage projects are generally prohibitive for many developing countries as discussed in Section 2.2. The financial base for many lake basin local governments or even central governments is often insufficient to undertake sewerage projects as was illustrated in both cases of the Bhoj Wetland and Lake Nakuru where the need for sewerage projects was recognized but the needed funds could not be mobilized locally. As such, sewerage projects often lag behind water supply projects, even though ideally both should be implemented concurrently. Mobilization of financial resources from donors, multilateral institutions and international financial institutions to meet the capital costs for sewerage projects is therefore often necessary. The lesson is:

- External financing for capital costs by donors, multilateral institutions and international financial institutions is critical to the implementation of sewerage projects in developing countries.

3.3.3 *Long-Term Planning*

Rapid population growth in many developing countries calls for a long-term approach in planning for sewerage services especially in urban lake basins like the Bhoj Wetland and Lake Nakuru. Sewage flows are projected to increase and outstrip the current treatment capacity at the STPs at the two study lakes in the next decade or so. Because of the high cost of sewerage projects, it is unrealistic to expect that the increasing demand for sewerage services can be fully met by a single project. Rather, a step-by-step approach that allows for implementation of feasible and cost-effective systems to reach long-term goals seems to be the most reasonable approach. The lesson to be learned is:

- High costs of sewerage systems and rapid population growth call for a long-term approach in planning for sewerage services in developing countries.

3.3.4 *Connectivity to the Sewer Network*

A sewerage system cannot achieve its intended objectives if connections to the sewer network are not ensured. In both case studies reviewed, the STPs are operating below their design capacity because of low connectivity to the sewer network. While the projects in the two study areas provided for the main sewer network, it was left to the residents to arrange their individual connections to the sewer network by themselves. Low connectivity may be attributed partly to the high cost involved and also to lack of awareness among the residents regarding the importance of sewerage system. In both case studies, it was not clear whether prior assessment of the preferences, willingness and ability to pay for the sewerage service was undertaken before implementing the projects. It was also not apparent how much efforts have been made to promote the sewerage service among the residents. The following lessons can be learned:

- It is essential to assess the willingness and ability to connect to the sewer network prior to implementing sewerage projects. As needed, facilitation of individual connections should be in-built in the project design.

- Efforts should be made to promote awareness about sewerage service among residents in the project area. This would not only increase willingness to connect but could also increase the willingness to pay for the sewerage service.

3.3.5 *Choice of Technology*

The choice of the appropriate technology for sewage treatment depends on several factors such as cost, existing social, cultural and physical conditions, etc. On-site systems, conventional wastewater treatment and natural systems are the most feasible options for developing countries. Advanced treatment for removal of nutrients is more expensive and therefore not feasible in these countries that cannot even afford conventional treatment. For conventional treatment, biological systems such as ponds (used in Bhoj Wetland and Lake Nakuru) that have low energy requirement than mechanical systems and are relatively cheap and easy to operate and maintain are most suited to developing countries. The lesson is:

- Cost effective technologies such as ponds and natural systems are the most feasible for developing countries.

3.3.6 *Operation of Maintenance*

Lack of proper operation and maintenance (O&M) was noted as one of the major problems in the two case studies, especially in Lake Nakuru where problems like sewage overflow, lack of periodic cleaning of rock filters and stormwater detention pond were common. This was mainly attributed to lack of funds for O&M because of very low priority accorded to sewerage in allocating the budget for O&M by the concerned Municipal Governments. It is often the case that other essential services such as water supply, healthcare and education receive higher priority in budget allocation than sewerage.

Lack of cost-recovery in sewerage service provision is also another factor that hinders O&M. In the Bhoj Wetland case, no user fee is directly charged for sewerage services. In the Lake Nakuru case, while a user fee is charged, it is very low compared to the O&M cost. While it is unrealistic to expect full cost recovery for capital costs and O&M costs, user fees should be set such that they meet at least the O&M costs if sustainability of sewerage systems is to be ensured. Additionally, other innovative financing mechanisms for O&M should be explored. Examples include mobilizing part of the revenues from the use of lake basin resources (water supply in the Bhoj Wetland and tourism in Lake Nakuru). The lessons to be learned are:

- Budget allocation for O&M of sewerage works is often inadequate because of low priority accorded to sewerage. However, if the costs and benefits of sewerage systems are properly accounted for in decision making, it would facilitate a paradigm shift to allocation of higher priority for sewerage works.

- User fee structures for sewerage systems should aim at ensuring full cost recovery at least for O&M costs. Also, other innovative financing mechanism, such as mobilization of part of the revenues from lake basin resource uses that benefit directly from sewage pollution control, should be considered.

3.3.7 Industrial Wastewater Treatment and Enforcement of Effluent Standards

Industrial effluents are best controlled by treating them at the source before they are discharged to the sewerage system. However, the case in most developing countries (including the two case studies reviewed here) is that industrial wastewaters are discharged to the sewerage system after undergoing simple pre-treatment (such as sedimentation) or no treatment at all. Because sewerage systems are not designed to remove industrial wastes, the wastes remain in the treated effluent from the STPs and eventually reach the lake environment. To meet the objective of pollution control of the lake environment, it is essential that installation of sewerage systems should be complemented by installation of industrial wastewater treatment facilities. Also important for effective industrial wastewater pollution control is strict enforcement of effluent discharge standards. In both the Bhoj Wetland and Lake Nakuru, while the relevant standards exist, lack of enforcement was noted to be a major problem. The lessons are:

- Installation of sewerage systems should be complemented by installation of industrial wastewater treatment facilities if the overall objective of pollution control of the lake environment is to be met.

- Strict enforcement of effluent discharge standards is necessary for industrial wastewater pollution control.

3.3.8 Monitoring and Evaluation

Monitoring and evaluation of performance of sewerage systems are essential to ensure that the installed systems are meeting their intended objectives such as quality of treated effluent. Therefore, installation of appropriate facilities such as water quality testing laboratories for monitoring is necessary and should always be included as a component of sewerage projects as was the case in the Bhoj Wetland and Lake Nakuru. Through monitoring and evaluation improvements can be made as needed. Also, monitoring and evaluation results provide the basis for making a strong case for sewerage works and the need for continued budget allocation, especially in situations where there are other competing needs for scarce financial resources.

However, a comprehensive evaluation of a sewerage system from a lake basin management perspective requires an understanding of all the pollution loads to the lake, including point and non-point source loads. While this is a task that is obviously beyond the scope of sewerage projects *per se*, it is only by doing so that it can be clarified whether the investment in sewerage works has a significant effect on total load reduction vis-à-vis investment in other measures for pollution control. Unfortunately, in the Bhoj Wetland and Lake Nakuru cases, it was not possible to carry out such an assessment because of lack of data. The lessons to be learned are:

- When designing sewerage schemes, monitoring and evaluation should be included as an important component.

- Although comprehensive assessment of all point and non-point sources of pollution to a lake is beyond the scope of sewerage projects *per se*, such an assessment is essential to evaluate the significance of sewerage works in reduction of total load input to the lake.

4. Conclusion

Access to adequate sanitation in developing countries remains a major challenge to the global community. With the current trend of population growth in developing countries projected to continue, lack of sanitation is bound to impact negatively on surface water bodies. Urban lakes will particularly be affected because it is projected that most people in developing countries will live in urban areas in the coming decades. Based on case studies of two urban lakes, namely the Bhoj Wetland and Lake Nakuru, this paper has argued that provision of sewerage systems in lake basins can be justified from the point of view of lake conservation, as opposed to the traditional justification from the viewpoint of protection of public health. For this purpose, long-term resource values of lakes need to be properly considered in the decision making process.

The major challenge of installing sewerage systems in developing countries is the high capital cost involved which is normally beyond the means of most developing countries. Financial facilitation by donors, multilateral institutions and international financial institutions is often necessary to meet the capital costs. For sustainability it is desirable that financing mechanisms that ensure full cost recovery for at least the O&M costs be applied. It is emphasized that the high cost of sewerage systems calls for a long-term approach in planning that allows step-by-step implementation of feasible and cost-effective systems to reach long-term goals.

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