Protecting Lakes from Urban Water Pollution with Sewerage Systems

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by Shinji Ide, Kosho Net

This presentation will briefly review the cases of twenty-eight lakes shown in Table 1 with a special focus on environmental infrastructure such as sewerage system in the basins. Although some lakes came short of relevant data, available information on these lakes shows that the current status of sewage system in individual lake basin is quite different from one lake to another. Some lakes are completely lacking wastewater treatment in the catchment areas while others are fully equipped even with tertiary treatment.

Affordability of Sewerage Systems

First, the extent of sewage treatment at the twenty-eight lakes was analyzed based on per capita gross national income (GNI[1]) of basin countries and population density in the basin. The results are summarized in Table 1. The extent and degree of wastewater treatment is indicated by the **bold** letters in each cell (e.g., **Rare or Low**). The classes of treatment are represented as **low** = primary, **medium** = secondary, and **high** = tertiary. For lake basins with low population density and low GNI per capita (cell I-1), almost no sewage treatment is carried out. As both income and density increase (I-2, II-1, II-2), conventional treatment systems expand, usually with bilateral funding. For high GNI per capita countries (III-1, III-2), even in sparsely populated areas (III-1) conventional and advanced treatment are carried out, usually with central or local government funding.

[1] GNI per capita 2002, Atlas Method (in US$) after World Bank Statistics at http://www.worldbank.org/data/databytopic/GNIPC.pdf

Table 1: Extent of Sewage Treatment at 28 Lakes

GNI per capita \ Population Density	1) < 100 person/km^2	2) >= 100 person/km^2
I) Low-Income Economies < 736 US$	I-1) Malawi, George, Tonle Sap, Issyk-Kul, Chad, Kariba, Tanganyika, Baringo, Chilika **Rare or Low**; Even n[illegible] plan	I-2) Victoria, Naivasha, Nakuru, Bhoj Wetland, Toba **Low to Medium** (in urban area) Funded by bilateral assistance
II) Middle-Income Economies 736 - 9,075 US$	II-1) Aral Sea, Baikal, [illegible] Ohrid, Xingkai/Khanka, [illegible] Peipsi/Chudskoe, Cocibolca-Nicaragua **Low to Medium** Partly funded by bilateral assistance	II-2) Dianchi, Laguna de Bay, **Low to High** [illegible] bilateral or the central [illegible]nt's assistance
III) High-Income Economies > 9,075 US$	III-1) Champlain, Great Lakes **High** + CSOs[1], SSOs[2] and USR[3] issues. Funded by the central and local governments	III-2) Constance, Biwa **High** Funded by the central and local governments

Notes: [1] CSOs: combined sewer overflows. [2] SSOs: sanitary sewer overflows. [3] USR: urban stormwater runoff.

Table 2 is cited from a draft municipal wastewater guidance document prepared by the United Nations Environment Programme, which shows ranges of costs for conventional wastewater treatment options. No information is available on how countries are divided into three economical classes in the table. If we could, however, assume that economical classifications in Table 2 were similar to the ones in Table 1, the following interesting relationship could be deduced from the two tables by comparison: Sewerage system is affordable only if its "capital plus operation and maintenance cost" per capita per year and "capital cost per capita" are less than approximately 2% and 20% of GNI per capita, respectively.

In other words, the capital cost of "Sewer + Treatment" would be far greater than affordable level and only treatment plants without sewer lines may be reasonable for Low-Income Economies with GNI per capita being less than 736 US$. Some affluent cities in Low-Income Economies could afford "Capital

Plus Operation and Maintenance Cost" in annual basis, but it is unrealistic for even those cities to manage to raise funds for the construction of sewerage system unless bilateral or multilateral financial assistances are available.

Likewise, some countries in "Middle-Income Economies", which GNI per capita is in between 736 and 9075 US$, may be able to bear "Capital Plus Operation and Maintenance Cost" in annual basis; however, they may not be able to incur the capital costs. Again some financial supports from developed countries or donor agencies are essential for those nations to develop sewage systems.

Table 2: Cost Ranges for On-site and Sewered (Conventional Treatment) Options

Economy	**Option**	**Capital Cost[1] ($/capita)**	**Capital Plus Operation and Maintenance Cost ($/capita/year)**
Low-Income Economies	Treatment plant[2]	20-80	5-15
	Sewer + treatment[2]	200-400	10-40[3]
Middle-Income and Transitional Economies	Treatment plant[2]	30-50[2]	Not provided
	Sewer + treatment[2]	300-500[2]	30-60[3]
Industrialized Countries	Treatment plant[2]	150-300[1]	Not provided
	Sewer + treatment[2]	100-200[2]	100-150[3]

Notes:

[1] For primary plus secondary treatment, including land purchase and simple sludge treatment, for a capacity of 30,000 to 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.

[2] For plant capacity of 100,000 to 250,000 persons.

[3] For industrialized countries, this includes tertiary treatment and full sludge treatment; for other countries, this includes secondary treatment.

Source: UNEP, 2001. "Guidance on Municipal Wastewater: Practical Guidance for Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) on Sewage." Working Document Version 2.0, 21 October 2001. The Hague: UNEP/GPA Coordination Office.

Principles for sewage system development

Principles in Box 1 and 2 are very informative in general for the installation of wastewater treatment, even though which are not exclusively for lakes and reservoirs. The Boxes summarize the key principles and experiences of the UNEP's wastewater guidance document mentioned previously and the World Bank, respectively. Many of the twenty-eight lakes are facing problems with wastewater treatment. Those problems are caused by neglecting one or some of principles in Box 1 and 2.

Box 1: Key Principles for Municipal Wastewater Management

1. **Political will and financial affordability are prerequisites for adequate wastewater management.**
2. **Environment, health, and economy are important indicators for action.**
3. **Stepwise implementation of measures is essential to reach long-term management goals.**
4. **Demand-driven analyses and prognoses ensure effective investments.**
5. **National and local governments are responsible for creating an enabling environment for sustainable solutions.**
6. **Commitment and involvement of all stakeholders are assured from the start.**
7. **"Water User Pays" and "Polluter Pays" are basic principles to consider.**
8. **Public-private partnerships and other new financial mechanisms should be explored.**
9. **Linking municipal wastewater management systems to other sectors, for example water supply or tourism, ensures better opportunities for adequate cost recovery.**
10. **Sustainable solutions for wastewater management build upon pollution prevention at the source, efficient water use and best available technologies, and address economic aspects and low-cost alternatives when appropriate.**
11. **Innovative alternatives and integrated solutions are to be fully explored before final decisions on action are taken.**

Source: UNEP, 2001. "Guidance on Municipal Wastewater: Practical Guidance for Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) on Sewage." Working Document Version 2.0, 21 October 2001. The Hague: UNEP/GPA Coordination Office.

The general objectives of wastewater treatment are to achieve 1) sanitation and 2) pollution control. Unfortunately, persons who bear costs for achieving those objectives may not be the same ones who benefit from the achievement. For example, wastewater treatment improves public health issues in the service area, but people downstream may not reap the direct benefits of the treatment. Improvement of water quality and pollution control of water bodies, from which drinking water is being taken, would be the primary concern for downstream people, but people upstream may not share the same concern. Wastewater treatment could engender a new conflict between upstream and downstream. However, lake basins are fortunate in this regard. The achievement of sanitation in the watershed results in the pollution control of lake simultaneously. People live in a lake basin share the common destiny. In this sense, consensus building of lake-people for wastewater treatment, apart from cost issues, can be much easier than the other areas.

Box 2: Key Lessons from the World Bank Experience with Wastewater Treatment Plants

1. **Assessing environmental issues from the beginning.**
2. **Using regional and multisectoral planning.**
3. **Creating extensive stakeholder involvement.**
4. **Using a demand-oriented approach.**
5. **Engaging the private sector.**
6. **Providing sufficient funds for operation and maintenance (O&M).**

Source: the World Bank, 2003. "Water Resources and Environment Technical Note D.2—Water Quality: Wastewater Treatment—"

Advanced treatment for eutrophication control

On the other hand, conventional treatment for removing carbonaceous matters may not be adequate for lake management as primary production in lakes and reservoirs cannot be negligible. Advanced or tertiary treatment for removing nutrients such as nitrogen and phosphorus is of necessity for eutrophication control of lakes. However, tertiary treatment is in general more costly than conventional one. Additional 30-50 US$/capita/year would be required for nutrient removal (see Table 3). Tertiary treatment cannot be reasonable for those countries that cannot even afford conventional one.

Wastewater may not be the sole and primary source of nutrients to lakes. The primary source can be air-born ones for some lakes. In this case, nutrient removal from wastewater may not be the most cost-effective way to achieve eutrophication control. Precise assessment of environmental issues is indispensable prior to decision-making concerning tertiary treatment. However, some kind of treatment such as basic or primary one is a prerequisite in any case for riparian big cities, even though it may not be sufficient for lake conservation. Stepwise implementation of measures is essential in general to achieve long-term lake management.

Table 3: Generally Applied Wastewater Treatment Methods

Method	Pollution Problem	Efficiency	Costs (US$/capita/year)[4]
Chemical precipitation	Phosphorus removal	0.65-0.95	7-13
Nitrification	Ammonia -> nitrate	0.80-0.95	15-22
Denitrification	Nitrogen removal	0.70-0.90	11-18
Waste stabilization ponds	Microorganism Reduction of BOD_5 Nitrogen removal	High 0.70-0.85 0.50-0.70	2-6
Constructed wetland	Reduction of BOD_5 Nitrogen removal Phosphorus removal	0.20-0.50[5] 0.70-0.90 0.00-0.80[6]	4-11

Notes:

[4] Originally the costs were estimated in US$/100 m^3. The author converted them into ones in US$/capita/year with the assumption that one person discharges 0.2 m^3 of wastewater per day.

[5] Presume a pretreatment (BOD_5 <= about 75 mg/L).

[6] The removal is dependent on the adsorption capacity of the soil applied and whether harvest of the plants is foreseen.

Source: United Nations Environment Programme—International Environmental Technology Centre, 1999. “Planning and Management of Lakes and Reservoirs: An Integrated Approach to Eutrophication.”

Nevertheless nutrient removal is highly recommendable in the long run for lake management. New financial mechanisms should be explored particularly for advanced treatment. Possibilities of bilateral and multilateral financial assistances and engagement of private sectors should be inquired for the eutrophication control of lakes. User fee could be one way to get private sector involved.

Moreover, the use of less expensive treatment technologies for nutrient removal should be first considered particularly for lakes and reservoirs. Some constructed natural systems such as ponds, lagoons and artificial wetlands are capable of removing 70-90% of nitrogen, and 0-80% of phosphorus (seen Table 3) from raw wastewater. Soil-based land treatment system is also very effective for phosphorus removal.

Timing of Water Supply, Conventional and Advanced Wastewater Treatment Development

Another key question over environmental infrastructures for lakes and reservoirs is the timing and methods of system development, more specifically, how water supply, conventional wastewater treatment and advanced wastewater treatment should be developed.

If we look into the cases of Lake Constance, Lake Biwa, and Lake Nakuru for the development history of environmental infrastructures, quite different characteristics in terms of development time frame can be observed in these three lakes.

As for Lake Constance, people in the catchment area have been provided with water supply service more than one hundred years. Installation of sewerage system came very late after the completion of water supply system. In 1972 only 25% of all inhabitants in the catchment area were connected to sewage plants with biological treatment. However, the percentage had increased rapidly since then to reach 90% in 1985 and over 95% in 2001. At the same time the percentage of sewage treated with phosphorus removal systems in the entire wastewater treatment increased from 24% in 1972 to 88% in 1985, and is 97% in 2001.

The population coverage of water supply at Lake Biwa basin was only 30% or so even in the 1950s, but in step with high economic growth in Japan, the percentage increased rapidly and reached 80% in the 1960s. However, one of sewage system still remained at a low percentage, and only 4% until the 1980s. Drastic improvement of sewage system in Shiga has started at last from the early 1980s, and it reached 70% today. In addition, partly because the installation of sewage system started very late, advanced treatment for eutrophication control has been implemented from the beginning with the sewage system development. Today, the percentage of advanced treatment in Shiga is the highest in Japan.

In sharp contrast to the above two lakes, full scale water supply system was first installed in the catchment area of Lake Nakuru in the early 1990s. However, as a result, old sewage treatment plant became unable to treat newly generated wastewater from this water supply, and much of wastewater began to come into the lake without treatment. To solve this problem, a large scale improvement project of sewage system started at Lake Nakuru several years later. However, no advanced treatment has been installed yet. This illustrates the necessity of multisectoral plan that we should consider the development of water supply system together with sewage system.

In short, water supply, sewage, and advanced treatment systems were adopted step by step at Lake Constance as well as other lakes in most developed countries. However, both sewage and advanced treatment systems were introduced simultaneously at Lake Biwa after the completion of water supply system. Even though Lake Nakuru had the above mentioned problem and do not have advanced treatment yet, it achieved the development of water supply and sewage system almost at the same time. These facts imply that, if financial arrangements are available, there is a possibility to develop those three systems simultaneously although stepwise implementation of environmental infrastructures is more realistic and common. The development of environmental infrastructures in a multisectoral manner would be more desirable to achieve long term goals for lake management.