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Sustainable Urban Wastewater Management and Reuse in Asia

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The aim of this paper is to introduce the concept of sustainable urban wastewater management in the Asian context. Sewerage systems are key facilities to support public health and sound development in urban areas. They exist in most of the rapidly developing cities of Asia; however, a range of practical, financial, political, and environmental factors mean that provision is often inadequate to meet current and projected demand. To meet clean water goals and reduce the environmental impacts of urbanization, sewerage systems should be incorporated properly into watershed management plans. The paper ends by examining some of the range of new and established technologies and methods that can help Asian cities and periurban areas to minimize the burden and maximize the potential benefits of urban wastewater.

Keywords: Asia, Wastewater treatment, Sewage treatment, Sewer system, Sustainability, Wastewater reuse.

1. Introduction and background

Sixty percent of the global population lives in Asia. In 1970, just over 20 percent of those people lived in cities. In 1990, almost 35 percent were living in urban centers. Projections by demographers for the United Nations put the level of urbanization in Asia at more than 56 percent by the year 2020, which means an additional 1.5 billion urban dwellers (Chia 2001a). The governments in these Asian countries have given priority to infrastructure projects that promote economic activity, such as power plants and ports, rather than to sewerage and water-treatment plants. Now, across the region, rapidly industrializing economies are seeing millions of migrants from rural areas attracted to urban centers. With few exceptions, Asian governments are failing to provide even the most basic urban environmental services, including sanitation and piped water supply, for much of their countries' burgeoning populations. This paper focuses particularly on treatment and management of wastewater.

There are deep underlying factors involved in the generally low coverage of sewerage services in urban areas in most Asian countries. The rapid pace at which urbanization is happening, combined with the low income levels of a large proportion of the population, is a basic factor. Much of the expansion of residential and industrial areas is uncontrolled. Many cities continue to suffer from high inflows of migrants from their rural hinterlands. Uncontrolled housing and, worse still, developments of illegal squatter colonies that often line the waterways running through urban areas constitute a major problem for city administrators. Under warm equatorial conditions and especially during the summer, high

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temperatures add to the problem of rapid putrefaction in polluted water; although, conversely, such conditions boost the effectiveness of sewage treatment plants because they increase the biological activity necessary to break down contaminants and inactivate pathogens. The presence of large amounts of garbage and other blockages reduces the natural flow of water through drains, canals, streams, and rivers, leading to stagnation. It is common to see water in these channels turning green and turbid because of algal bloom. Mass fish deaths resulting from harmful algal blooms or red tides have become a serious problem in many parts of Asia, especially the Philippines and China, resulting in closure of fisheries, loss of income and employment, and damage to health. Untreated sewage is a likely cause of these conditions.

In most cities, there is only a rudimentary centralized sewerage system and the larger part of wastewater is discharged without treatment into rivers, lakes, and coastal waters. In the advanced economies of Japan, Hong Kong, and Singapore, cities have reached the standards of the best Western metropolises. Most cities in East Asia suffer from a lack of financial and technical resources to undertake the construction of large-scale centralized sewerage systems. Even though the major cities where the wealth of the nations is concentrated would have the resources to build and maintain an adequate sewerage system, several do not do so. The problem appears to be one of political will; sanitation does not directly generate revenue and it is not a visible benefit even for those urban dwellers who have their homes connected to a public sewer. It is also understandable that more attention is given to the provision of safe water through the construction of water-supply systems, which cost a tenth of the investment for a sewerage system and have more visible benefits. Some other obstacles that stand in the way of sustainable wastewater management in urban Asia are examined in section 3.

The aim of this paper is to introduce the concept of sustainable urban wastewater treatment in the Asian context. The first part provides a general overview of wastewater treatment in industrialized Asian countries and the second part discusses different sustainable examples suitable for large metropolises and for, medium-sized and small cities.

2. Sewerage, drainage, and on-site sanitation systems in urban Asia

In most situations, gravity sewers following natural topography are used for collecting sanitary sewage. The components of a typical system are described below:

- *House connections*, also referred to as building sewers, connect to building pumping systems. Normally, the house connection begins outside the building. In most municipalities, existing septic tanks are taken out of service when a building is connected to the sewerage system.
- *Laterals* are the first level of municipal sewers serving a group of houses. They usually have a minimum diameter of 150 mm and are located in streets or special easements.
- *Main sewers collect sewage from several laterals.*
- *Trunk sewers* are the largest elements of a sewerage system, delivering raw sewage to treatment facilities or disposal points.

The earliest recorded drainage and sewerage developments in the Asian region were constructed as combined systems (that is, sewerage and drainage combined) for old cities. This was an accepted design practice in the early twentieth century and provided an economical solution to the wastewater collection problem. Many were designed to function as urban drainage systems. As communities grew, many people discharged their sanitary waste into the stormwater drainage, and raw sanitary sewage was then conveyed to natural receiving water. With increased population, the large volumes of sewage being discharge led to water pollution problems. Wastewater treatment was then necessary.

The existing drainage systems in the urban areas of developing Asia, which almost entirely consist of drains, canals, and combined sewers without pumping stations, are generally in poor condition due to lack of maintenance. They are poorly designed and constructed, without sufficient hydraulic capacity. Drainage coverage is unevenly developed in the various cities. In recent years, many Asian cities have suffered from inadequate infrastructure, including water treatment and supply. The problem has become chronic in the wake of the burgeoning of urban populations in the large cities, where sewerage and water-supply projects have lagged behind population growth. This leaves large proportions of the populations unserved, as can be seen in table 1.

Table 1. Water service and sewerage coverage in some cities in Asia Pacific areas

	Bangkok	Calcutta	Dhaka	Jakarta	Karachi	Manila	Seoul	Shanghai	Tokyo
Water service coverage, %	82	66	42	27	70	67	100	100	100
Water availability, m^3/day	24	10	17	18	14	17	24	24	–
Production, million m^3/day	3.85	1.20	0.78	0.97	1.64	2.8	4.95	4.7	4.54
Per capita domestic wateruse, L/day	265	202	95	135	157	202	209	143	245
Sewerage coverage, %	10	3.2	28	–	83	16	90	–	100

Source: UNEP 2002.

At present, sewerage and drainage systems in most of the developing countries in Asia, particularly India, Bangladesh, Sri Lanka, Nepal, the Philippines, and Vietnam, are in very poor condition. Those systems were constructed during colonial times and need to be upgraded and/or rehabilitated. For example, in India at present, the sewerage network in Mumbai consists of almost 1,381 km of main sewerage line in a combined system, and only 51 pumping stations.

Septic tanks are the most prevalent form of on-site urban sanitation in the developing countries of Asia, for both flush and pour-flush toilets. This is due to their practicality, being easier and cheaper to implement in densely populated areas. About 80 percent of the total population in urban Asia uses septic tanks.

Because of small lot sizes in typical urban areas, septic tank effluents overflow into roadside drains even where subsoil soakage is attempted. Some of these roadside drains are clogged by domestic and commercial solid waste and other debris. In urban areas with waste-disposal systems, sewage (human excreta and bathing wastewater) are directed predominantly to septic tanks. Graywater (kitchen, laundry, and other non-toilet wastewater) may or may not be conveyed to septic tanks.

3. Key constraints in wastewater management in urban Asia

The need for modern wastewater management is now widely recognized in Asia, especially in the larger cities. However, for several reasons, systems are not sustainable and fail to meet the real demand. This section examines some of the constraints to sustainable wastewater management.

3.1. Insufficient funding

While there has been significant progress over the past decade in constructing new facilities, there remains a large backlog of unmet investment needs. With the large investments necessary, the sector would greatly benefit from additional sources of financing, including debt over the shorter term and private-sector equity investment over the longer term. These would rely on direct cost recovery from user charges.

3.2. Lack of cost recovery

User charges are implemented in only a few municipalities. The adoption of user charges by municipalities has been slow primarily due to the lack of political will and public acceptance. The lack of cost recovery is a major obstacle to private-sector participation, which could play a major role in addressing the existing funding and skills shortages in the sector. To overcome public resistance, the “polluter pays” principle should be promoted in public in the context of wastewater treatment.

3.3. Sustainability of services

In addition to inadequate collection systems and poor plant design, serious deficiencies also exist in the funding of operations and maintenance. This affects the quality and sustainability of services. This is due primarily to reliance on public-sector operation and maintenance, lack of options for cost recovery, and inadequate enforcement of existing environmental regulations.

3.4. Shortage of technical skills

Technical skill shortages are a major factor responsible for poor performance in operation and maintenance. The lack of private-sector participation and better job incentives in the private sector exacerbate this shortage. The concept of the public-private partnership (PPP) should be introduced to improve skill levels in the private sector and to find possible solutions for this shortage.

3.5. Inadequate enforcement

In developing countries, there are presently no regular programs for monitoring discharges from existing municipal wastewater facilities or for penalizing municipalities with inadequate or no treatment facilities. With low environmental awareness, active enforcement tends to be the primary catalyst in driving environmental improvement programs.

4. Overview of urban wastewater management in selected Asian countries

This section examines the status of wastewater management in several Asian countries and cities. As can be seen, in most countries wastewater treatment is an innovation of only the last few decades, a response to rapid urban development. In some countries, however, sewerage and drainage have much longer histories.

4.1. Malaysia[1]

Sewerage management in Malaysia was under the jurisdiction of local authorities prior to 1993. The standards of sewerage services varied widely around the country, due to difference in management skills and financial resources among different local authorities. To address this problem, in 1993, the Malaysian government decided to centralize management of sewerage services around the country at the federal level and introduce private-sector participation. The Department of Sewerage Services was formed under the Ministry of Housing and Local Government to act as regulator of the sewerage industry.

A national concession company, Indah Water Konsortium Sdn Bhd (IWK), was formed in April 1994 to undertake management of sewerage services in Malaysia. According to the Malaysian Sewerage Services Department, to date, IWK has taken over the management of sewerage services from all local authority areas in Peninsular Malaysia, except for Majlis Bandaraya, Johor Bahru, and Kelantan, as well as in the Federal Territory of Labuan. As of November 2003, IWK operated and maintained 12,500 km of sewers, 7,502 sewage treatment plants, and 444 network pumping stations. It also serviced septic tanks for some 350,000 customers, and was considering providing on-demand services for the remaining 600,000 septic tanks in the country.

IWK formulated the 2004–2035 Sewerage Development Plan (SDP), which is a development strategy to improve sewerage infrastructure in the country. The SDP recommends the most appropriate disbursement of capital funds to meet actual sewerage needs. It includes defined targets. The overall target for 2035 is to serve 80 percent of the population with connected services.

In addition to the SDP, Malaysia is now implementing sewerage projects under the Eighth Malaysian Plan Allocation. One of the investment sources for these projects is a loan from the Japan Bank for International Cooperation (JBIC). The JBIC projects cover 13 urban areas and includes upgrading of 10 sewage-treatment plants and seven sewerage network packages, and the provision of three new central sludge-treatment facilities. The construction of the projects comes in three packages. Construction work for Phase 1 started in January 2004. Details of the different plants being built under the projects are provided in table 2.

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[1] This section on Malaysia is based on Maniam 2004, with minor alterations.

Table 2. Sewage-treatment plants, centralized sludge-treatment facilities, and sewerage networks being constructed under the Malaysian sewerage projects

Code: plant name	Population equivalent (PE) and flow, m^3/day	Treatment plant type and treatment flowsheet
A1: Bunus sewage-treatment plant (STP)	352,000 PE, and flow: 87,000.	Advanced Activated Sludge Process (ASP); screen; grit plus oil and grease (O&G) removal plus rectangular primary settling tank (PST) plus aeration tank plus secondary settling tank (SST) anaerobic digestion (ambient temp, circular digesters). Mechanical dewatering of anaerobic digestion (AD) sludge by screw press plus odor control facility.
A2: Pantai STP and network	377,000 PE, and flow: 93,000.	Screen; grit plus O&G removal plus rectangular PST plus aeration tank plus SST; anaerobic digestion (ambient temperature, circular digesters); mechanical dewatering of AD sludge by screw press plus odor control facility.
A3: Damansara STP	100,000 PE, and flow: 25,000.	Activated Sludge Process (ASP) with mechanical dewatering.
A4: Bandar Tun Razak STP	100,000 PE, and flow: 25,000.	Sequencing Batch Reactor (SBR) process; screen plus grit plus O&G plus flow balancing tank plus SBR (six rectangular tanks, submersible aerators); mechanical dewatering of AD sludge by screw press plus odor-control facility.
A5: Puchong STP and network	150,000 PE, and flow: 37,000.	Screen; grit plus O&G removal plus rectangular PST plus aeration tank plus SST; mechanical dewatering of AD sludge by screw press plus odor-control facility.
B1: Sungai Nyior STP and network	150,000 PE, and flow: 37,000.	Advanced ASP with PST and SST; mechanical dewatering.
B2: Juru STP and network	50,000 PE, plus transported sludge from septic tanks and small wastewater-treatement plants (WWTPs): 300,000 PE.	ASP and mechanical dewatering.
C1: Sunggala STP and network	60, 000 PE, plus transported sludge from septic tanks and small WWTPs: 50,000 PE.	Extended aeration ASP; mechanical dewatering.
C2: Kuala Sawah STP and network	360, 000 PE.	ASP; mechanical dewatering.
D1: Southern Klang Valley centralized sludge-treatment facility (CSTF)	Sludge from septic tanks plus small WWTPs: 400,000 PE (330 m^3/day), plus 20,000 PE sludge from WWTPs.	Mechanized thickening plus screw press dewatering; STP for wastewater from sludge treatment plus 5,000 m^3/day from 20,000 PE; three-stage step aeration anoxic-aerobic process with suspended biopellets to enhance nitrification.
D2: Sungai Udang CSTF	Sludge from septic tanks and small WWTPs: 300,000 PE.	Mechanical dewatering. ; STP for wastewater from sludge treatment.
D3: Kota Setar CSTF	Sludge from septic tanks and small WWTPs: 400,000 PE.	Mechanical dewatering. ; STP for wastewater from sludge treatment.

Source: Based on personal communication from Nishihara Environment Technology, Inc. on the Malaysian sewerage projects.

4.2. Thailand

Prior to 1990, there was virtually no treatment of municipal wastewater in Thailand. By the end of 1995, 25 wastewater-treatment systems—two in the northern region; seven in the northeastern region; nine in the central region; five in the eastern region; and two in the southern region—had been constructed, with a combined treatment capacity of about 430,000 m^3/day. In spite of such progress, the available total capacity was sufficient to serve just over 10 percent of the urban population in 1995. For the period 1995–1999, the Royal Thai Government budgeted about US$950 million for capital investment for construction and/or expansion of 40 additional facilities. However, following a 38-percent reduction in capital investments due to the 1997 economic crisis, the implementation schedule suffered significant delays and in some cases investments were cancelled. To date, 57 wastewater treatment plants have been constructed in 50 municipalities at a total cost of almost 19 billion baht (US$500 million).[2] About 75 percent of the treatment capacity provided by these systems has entered service only over the past four years. Another 28 facilities are presently under construction or undergoing expansion (World Bank 2001).

Although the served population is much lower due to problems with operation and collection, it is estimated that there is enough wastewater treatment capacity to cover 29 percent of the municipal population and, after the completion of those facilities that are under construction or undergoing expansion, this will increase to 65 percent (see table 3) (World Bank 2001).

Table 3. Municipal wastewater-treatment system capacity in Thailand

	Existing treatment plants		Existing plants plus those under construction	
Region	Capacity (m^3/day)	Municipal population covered (%)[1]	Total capacity (m^3/day)	Municipal population covered (%)
North	83,600	22	139,500	37
Northeast	106,650	19	170,710	31
Central	164,350	23	399,850	57
South	102,950	35	233,650	51
East	214,400	85	326,300	85
Bangkok Metropolitan Area	270,000	27	992,000	98
Total	941,950	29	2,262,010	65

Note: Capacity in excess of the needs of the municipal population for certain tourist provinces in the eastern, southern, and central regions is not included, as this capacity is designed to cover the tourist population.

1. Refers to population covered by the capacity.

Source: World Bank 2001.

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[2] Calculated at 38 baht/US$.

The treatment plants primarily consist of proven and relatively simple technologies, such as oxidation ditches, aerated lagoons, and stabilization ponds (see figure 1). These systems have low upfront capital and operation and maintenance (O&M) costs. Although the activated sludge process is promising and stable, it is relatively complex and costly to build and operate. It is used in some urban areas of the central region and the Bangkok Metropolitan Region, where land prices or availability limit the application of other technologies.

Thailand has been only moderately successful in operating wastewater treatment plants. About a third of the existing plants have major malfunctions or do not operate (World Bank 2001). The major reason for this is the inadequacy of funds to cover O&M. This shortfall was revealed in a 1999 survey of 29 facilities, which showed that most facilities suffered from equipment failure or damage as well as deficiencies in staff skill levels. The effectiveness of wastewater treatment systems in Thailand is also limited by the condition of the collection systems. Typically, wastewater collection systems in Thailand rely on old drainage systems comprised of canals or open sewers and poorly maintained drainage pipe networks with limited connections. Investment has primarily focused on intercepting the flow from these systems, with little focus on rehabilitation of the drainage networks themselves. As a result, the collection efficiency of these systems is low. Performance data on 19 plants has shown that these collection systems can, on average, collect only 55 percent of the wastewater that the treatment plants are designed to treat (World Bank 2001). In addition to making almost half the capacity of these plants redundant, inadequate collection has, in many cases, interfered with proper operation of treatment plants.

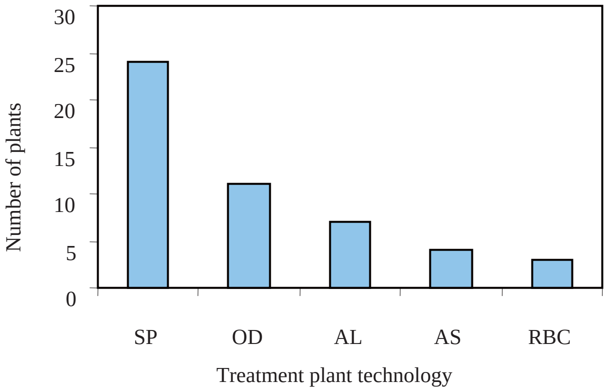

Figure 1. Types of technologies in existing wastewater treatment systems in Thailand

Key: SP = stabilization pond; OD = oxidation ditch; AL = aerated lagoon; RBC = rotating biological contactor.
Source: World Bank 2001.

4.3. Indonesia and the Philippines

At present, only five large cities in Indonesia operate centralized sewage-treatment plants: Jakarta, Bandung, Medan, Yokjakarta, and Cirebon. Construction of the Jakarta treatment plant was completed in 1992. However, it serves less than five percent of the population. Bandung started the construction of its plant in 1980 and it came into operation in 1990, serving nearly the whole population. Medan started construction of its system in 1985 and the work was completed in 1995, covering 75 percent of the population (UNEP 2002). Cirebon required three years for the construction of its plant, which was completed in 1991. Only around 15 of the 1,500 cities in the Philippines have domestic and industrial wastewater treatment facilities. Table 4 shows details of treatment plants for selected cities in the Philippines (UNEP 2002).

Table 4. Wastewater treatment plants in the Philippines

Cities	Capacity of the wastewater treatment m3/day	Type of the treatment	Remark
Ayala	40,000	Activated sludge	Operating
South Manila	207,000	Aerated lagoon	Under construction
Central Manila	162,000	Oxidation ditch	Under construction
North Manila	282,000	Aerated lagoon	Under construction
Dagut	12,600	Aerated lagoon	Under construction
Banguio	20% wastewater	Oxidation pond	Operating
Cauayan Isabela	30% wastewater	Activated sludge	Operating

Source: UNEP 2002.

4.4. Republic of Korea

The beginnings of sewage works in the Republic of Korea can be traced to the dredging and reconstruction of the Cheong Gye River, which flows through Seoul City, in 1412 during the Lee Dynasty. Under Japanese rule, records show that large-scale construction of storm sewers was conducted. However, the construction of modern sewerage systems started only after it was realized that they were the most important counter-measure for the widespread water pollution problems being caused by rapid urbanization during the period of high economic growth in the 1970s. As a result, the first sewage-treatment works, namely the Cheong Gye River Sewage Treatment works, (conventional activated sludge process with treatment capacity of 150,000 m^3/day, presently combined with Chun Nam Jong Sewage Treatment Works), was constructed and commenced operation in 1976.

Thereafter, sewage-treatment plants have continuously been constructed to prevent pollution of public waters such as rivers as industrialization and rapid urbanization progress. As of 1998, there were 114 sewage treatment plants (with a treatment capacity of 16.62 million tons per day), serving 66 percent of the population. Figure 2 shows the growth in the total capacity of the Republic of Korea's sewage-treatment facilities between 1993 and 2002. Secondary treatment (activated sludge process) is the most common treatment method used in the country. Although sewage-treatment facilities are well established in urban areas such as Seoul, Kwangju, and Taegu, rural areas are still behind; in Chonnam, less than 11 percent are served. Most of Korea's sewage-treatment plants treat biological oxygen demand (BOD) and suspended solids (SS) from the wastewater and do not attempt nitrogen and phosphorus removal (nutrients included in the wastewater that cause algal blooms). However, introduction of advanced treatment processes for nitrogen and phosphorus removal is underway (Ministry of Environment Korea 2004; Water Korea 2001).

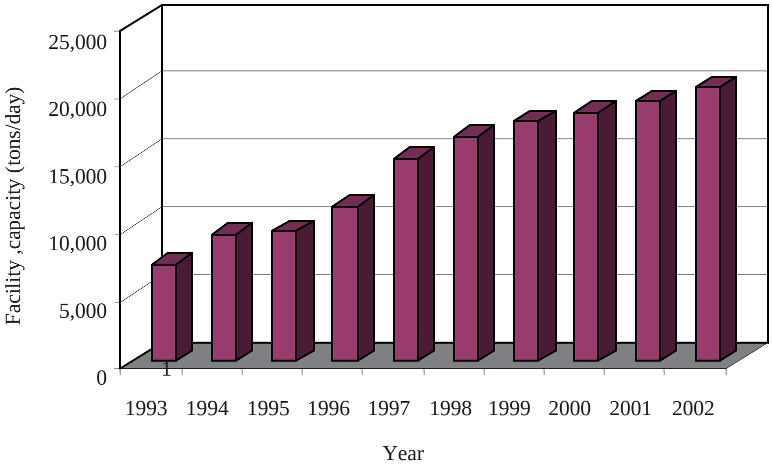

Figure 2. Sewage-treatment facilities in the Republic of Korea

Source: Ministry of Environment Korea 2004.

4.5. Japan

Modern sewer systems in Japan originated in 1884 in the Kanda district of Tokyo. The first cities to develop sewerage systems in Japan, which included Tokyo and Osaka, were located on lowlands vulnerable to flooding. These cities adopted combined sewer systems that could control both water pollution and flooding to some extent. Combined sewer systems were also easier and cheaper to construct than separate sewerage and flood-control systems. In the revised Sewerage Law in 1970, it was clearly stated that sewers were indispensable in maintaining the water quality of public water bodies. Almost all municipalities have since then adopted separate sewer systems, which are more effective in preventing pollution of public water bodies.

Investment in sewer systems has been sharply increasing since the 1970s, driven by systematic investment under five-year plans. The connected population rate increased sharply from 8.3 percent in

1965 to 66.7 percent in 2003, supported by a rapid increase in sewerage facilities. The total pipeline length is now 345,000 km; secondary and advanced treatment plants in operation number approximately 1,760 and 80, respectively (Japan Sewage Works Association 2004).

Table 5. Number of sewage-treatment plants in Japan

Sewage treatment process (number of plants)	Design treatment capacity in dry weather (1,000 m^3/day)						Total
	Less than 5	5–10	10–50	50–100	100–500	More than 500	
Primary treatment	1	–	1	–	–	–	2
Secondary treatment	906	160	383	143	155	16	1,763
Advanced treatment	22	2	23	10	23	–	80
Total	929	162	427	153	178	16	1,845

Source: Japan Sewage Works Association 2004.

While Japan has focused on development and expansion of sewerage systems, these systems have recently been expected to contribute to efforts to build a sound-water-cycle society and recycling society through utilization of the potential resources and accumulated stock of sewage. For example, treated wastewater has been utilized as a resource for various uses such as toilet flushing and restoration of streams. Although only one percent of the treated wastewater is reclaimed, the concepts of sprinkling reclaimed water onto water-retaining pavement and utilizing sewage heat have been investigated to ameliorate the “heat island” effect in Tokyo.[3] These are examples of attempts towards environmentally friendly wastewater management.

4.6. India

Discharge of untreated domestic wastewater is a predominant source of pollution of aquatic habitats in India. Urban centers contribute more than 25 percent of the sewage generated in the country. Smaller towns and rural areas do not contribute significant amounts of sewage due to the low per-capita water supply; any wastewater generated normally percolates into the soil or evaporates. The Central Pollution Control Board (CPCB) conducted a survey in 1994–95 on water supply and wastewater generation, collection, treatment, and disposal in 299 “class-I” cities (that is, with a population greater than 100,000) and 345 “class-II” towns (population between 50,000 and 100,000) (UNEP 2001). The survey findings indicated that most cities did not have organized wastewater collection and treatment facilities. Furthermore, the facilities constructed to treat wastewater did not function properly and were out of action most of the time due to flawed design and poor maintenance, together with a non-technical and unskilled approach to their management. The salient features of water supply and sewage treatment in urban India are given below, based on the findings of the 1994–1995 survey. These descriptions are

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[3] The “heat island” effect is elevated temperature conditions over an urban area caused by the heat absorbed by structures and pavement.

adapted from Central Pollution Control Board 2000a (class-I cities) and Central Pollution Control Board 2000b (class-II towns).

a. Class-I cities

In 1994–1995, the total population of 299 class-I cities, including 23 metropolitan cities, was 139,966,369. Maharashtra state and the Ganga River basin had the highest concentration of class-I cities.

The total quantity of water supplied to the 299 class-I cities was 20,607.24 million liters per day (MLd) and the wastewater generated was 16,622.56 MLd.

The proportion of the population covered by organized water supply was 88 percent and the average per-capita water supply in class-I cities was 183 liters per capita per day (Lpcd), which was an improvement of about 22 percent over the situation in 1988.

Some 70 percent of the population in class-I cities was covered by sewerage facilities, and the volume of wastewater collected was 11,938.2 MLd.

Total available wastewater treatment capacity was 4,037.2 MLd—32 percent of the wastewater collected and about 24 percent of the wastewater generated. Only 76 out of a total of 299 class-I cities had sewage-treatment plants, with either primary or secondary level of treatment.

b. Class-II towns

According to the 1991 census, there were 345 class-II towns with a total population of 23,645,614. The overall population density in class-II towns in 1994–1995 worked out to 3,695 persons per km^2.

At the time of the survey, the total quantity of water supplied to 345 class-II towns was 2,030.9 MLd, and wastewater generated was 1,649 MLd. The projected generation of sewage for the year 1999 was 1,897 MLd.

The percentage of population covered by organized water supply was 88, and the average per capita water supply in class-II towns was 103 Lpcd, an improvement of about 22 percent over the 1988 water supply values.

The percentage of the population covered by sewerage facilities in class-II towns was 66, and the volume of sewage collected was 1,090 MLd.

The total available wastewater treatment capacity was just 61.5 MLd, or about six percent of sewage collected and about four percent of sewage generated. Out of 345 class-II towns, only 17 had sewage-treatment plants.

c. Pollution-reduction plans

In the late 1980s, the Government of India launched the National River Action Plan (NRAP). Under this plan, certain stretches of major rivers with high or intermediate levels of pollution were identified by the CPCB. These areas were then given their own action plans and prioritized for development of sewage collection and treatment works to reduce the pollution load to the rivers. These included schemes for better interception and diversion of sewage, construction of sewage-treatment plants, provision for low-cost sanitation, among others. In the first phase of the Ganga River action plan, 29 towns were selected along the river and 261 pollution-reduction schemes were sanctioned. At present, 156 towns are being considered under the NRAP, out of which about 74 towns are located on the Ganga; 21 on the Yamuna; 12 on the Damodar; six on the Godavari; nine on the Cauvery; four each on the Tungbhadra and Satluj; three each on the Subarnarekha, Betwa, Wainganga, Brahmini, Chambal, and Gomti; two on the Krishna; and one each on the Sabarmati, Khan, Kshipra, Narmada, and Mahanadi (UNEP 2001). To address pollution of urban lakes subjected to anthropogenic pressures, the National Lake Conservation Plan (NLCP) of 1993 was prepared. The Bhoj Lake of Madhya Pradesh is already getting assistance thanks to funds provided by the Overseas Economic Cooperation Funds, Japan.

4.7. China

Wastewater treatment and reuse in China began in 1956, in the north of the country. Municipal wastewater is treated to primary and secondary standards, with secondary treatment being provided by (i) conventional activated sludge processes; (ii) contact-stabilization processes; or (iii) pure-oxygen aeration processes. In some cases, biological treatment facilities such as oxidation ponds and sewage irrigation systems are used as secondary treatment alternatives. Presently, total wastewater from cities and towns in China amounts to about 99.6 million m^3. It is estimated that only 123 out of China’s 668 cities have wastewater-treatment plants (307 plants in total), and only nine percent have secondary treatment. Of China’s 17,000 towns, most do not have drainage systems or wastewater-treatment facilities. Some Chinese cities have secondary wastewater treatment plants built, but not in operation, one of the reasons being the incomplete status of the associated wastewater-collection system; the investment required to establish a well-organized wastewater system with adequate piping and pumps is much higher than the expenditure on the treatment plants themselves.

5. The watershed approach to wastewater management

The watershed approach is essential for effective water pollution control, and sewerage systems should be allocated properly in watershed management plans. A watershed can be defined as the entire land area that ultimately drains into a particular watercourse or body of water. Watersheds can be many different shapes or sizes. The watershed approach is a decision-making process that reflects a common strategy for information collection and analysis as well as a common understanding of the roles, priorities, and responsibilities of all stakeholders within the watershed. Focusing on the whole watershed helps to identify the most cost-effective pollution-control strategies to meet clean water goals, to achieve the best balance among efforts to control point-source pollution and non-point pollutant run-off as well as to protect drinking water sources and sensitive natural resources such as wetlands. Each region should make a watershed-based plan for water pollution control.

Four main features are typical of the watershed approach: (1) identifying and prioritizing water quality problems in the watershed; (2) developing increased public involvement; (3) coordinating activities with other agencies; and (4) measuring success through increased and more efficient monitoring and other data gathering. Wastewater management should be incorporated into the water cycle, coordinating with whole-watershed management.

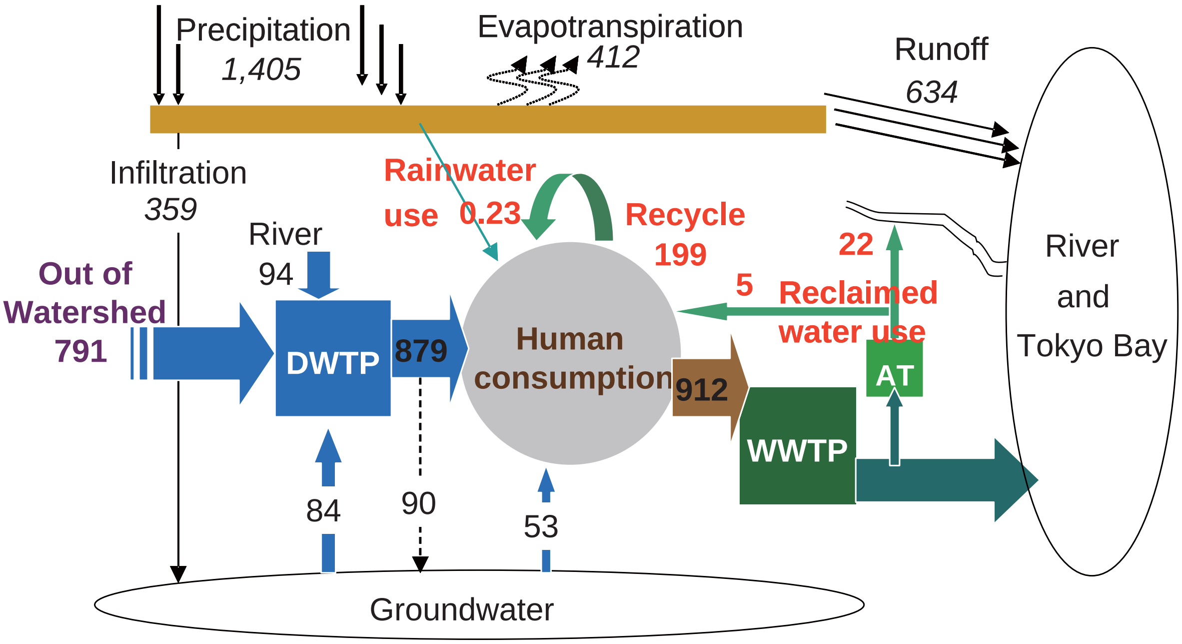

Figure 3. Water flow balance in Tokyo

Unit: mm/year.
Source: Tokyo Metropolitan Government 1999.

One example of a watershed management plan is the Tokyo Metropolitan Government's Master Plan for Water Cycle (Tokyo Metropolitan Government 1999). In making the plan, the metropolitan government figured out the water-flow balance in Tokyo. This is shown figure 3, in which the amount of water flow is expressed in rainfall equivalent annual rates (mm/year). This diagram clearly shows that a lot of water is introduced from outside the Tokyo watershed. This makes it reasonable to use reclaimed water to reduce water intake from natural waterways and mitigate the impact on the sound water cycle within the watershed.

6. Technology options for wastewater treatment

Technologies for both collection and treatment of wastewater should be selected to protect public health and the environment while ensuring the optimum use of water resources. This section looks at technology options that could be considered for wastewater treatment in Asia at three scales: large scale (for large cities such as regional and provincial hub cities, population equivalent >100,000), medium scale (for medium-sized cities such as provincial cities or towns, population equivalent 30,000–100,000), and small scale (decentralized systems for peri-urban areas, population equivalent <2000). The sections following look at some other technologies, approaches, and concepts that can complement these wastewater treatment technologies in order to move toward sustainable wastewater management.

There are cogent technical and managerial reasons for Asian countries to seek innovative solutions to the provision and management of sanitation for cities. These include the following:

- The high cost of sewerage systems;
- Lack of financial resources and availability of trained manpower;
- Dry conditions and water shortages;
- Realizing the potential value of waste materials from sewage; and
- Utilizing the untapped energies of the private sector and the people.

6.1. Large-scale urban

There are various options for centralized wastewater treatment for big cities. Large-scale municipal wastewater-treatment plants serve the larger populations of established cities and sometimes provide treatment and disposal services for neighboring sewerage districts. The advantages of large centralized systems include economies of scale; more control over operations; and a single management and workforce. There are various kinds of large-scale wastewater treatment plant. The most commonly used are the conventional activated sludge process or its variants, such as modified aeration and oxidation ditches. There are other lower-cost technologies, such as stabilization ponds and aerated lagoons, but these require a lot of space and are thus better suited to medium-sized or small cities where land is easily available. Table 6 shows the results of a comparison of the costs of various treatment processes by the Bangkok Metropolitan Authority.

Table 6. Cost comparison of various wastewater treatment processes

Ranking (1 = best)	Initial cost	O&M cost	Lifecycle cost	Operability	Reliability	Land area	Sludge production	Power use	Effluent quality
1	MA	SP	MA	SP	SP	MA	SP	SP	SP
2	AS	MA	AS	AL	AL	AS	AL	MA	AL
3	OD	AL	OD	OD	OD	OD	OD	AS	MA
4	AL	AS	AL	AS	MA	AL	AS	AL	OD
5	SP	OD	SP	MA	AS	SP	MA	OD	AS

Key: SP = stabilization pond; AL = aerated lagoon; OD = oxidation ditch; AS = conventional activated sludge; MA = modified aeration sludge or trickling filter solids contactor.

Note: Flexibility and expandability are similar for all types. Sensitive regions should be designated to protect against water pollution and eutrophication. In some cases, advanced treatment is needed.

Source: UNEP 2002.

If the treated wastewater is to be discharged into enclosed water bodies, estuaries, etc., a nutrient-reduction program should also be considered. Under EU guidelines, for rivers and streams reaching lakes, reservoirs, or closed bays that are found to have poor water exchange, whereby accumulation may take place, the removal of phosphorus should be included unless it can be demonstrated that the removal will have no effect on the level of eutrophication. Where discharges from large agglomerations are made, the removal of nitrogen may also be considered (European Economic Community 1991).

Case study: Yannawa sequencing batch reactor plant[4]

One of the most promising processes for large-scale wastewater treatment is the sequencing batch reactor (SBR) process. In the SBR process, inflow, reaction, and settling take place in one tank. By changing cycle times or providing intermittent aeration, the same plant can be used for nutrient removal. One interesting example is the Yannawa SBR plant in Bangkok.The treatment plant (phase 1), utilizing the Cyclic Activated Sludge System,from the company Earth Tech, was the first ever major multi-level wastewater facility constructed. The plant is designed to achieve a very high effluent standard, including nitrogen and phosphorus removal. The effluent limits are BOD of 20 mg per liter (mg/L), SS 30 mg/L, total nitrogen 10 mg/L, ammonia nitrogen 5 mg/L, and total phosphorus 2 mg/L. It is designed to accommodate large fluctuations in biological and hydraulic load automatically.

The Yannawa plant provides wastewater collection and treatment for the Bangrak, Sathorn, Bang Khor Laem, and Yannawa districts of Bangkok, with a combined area of approximately 2,855 hectares. The present population of approximately 500,000 is expected to double by the year 2020.

6.2. Medium-scale urban

The selection process for wastewater treatment facilities for smaller cities should factor in the costs and availability of land, labor, equipment, and building materials and the cost, availability, and reliability of support services such as utilities, equipment, and systems maintenance. Technology selection objectives that should apply in most developing countries include:

- Technological simplicity;
- Minimal capital and operating costs;
- Maximum treatment and removal efficiency for capital and recurrent investment; and
- Water reclamation and reuse capability to offset costs.

As discussed earlier, the activated sludge process and its variants are the most efficient, but their main disadvantage is in the high upfront and O&M costs. In medium-sized cities, funds are generally limited and land prices are not high. In these contexts, the most promising technologies are stabilization ponds, upflow anaerobic sludge blanket (UASB) reactor, or a UASB reactor combined with a polishing pond or other post treatment technology. These are examined in more detail below.

a. Stabilization ponds

Stabilization pond technology is eco-friendly and simple to operate. They can be constructed and maintained by the local community and are not dependent on power. Stabilization pond technology is recognized as the only cost-effective technology capable of killing pathogens to make the levels of microbial pollution in treated wastewater safe for agriculture, aquaculture, and bathing. Land is the primary requirement for waste stabilization pond technology (National River Conservation Directorate 2002).

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[4] This case study is based on the project description in Earth Tech 2004.

b. Upflow anaerobic sludge blanket reactor

The UASB is a high-rate suspended-growth type of reactor in which a pre-treated raw influent is introduced from the bottom of the reactor and distributed evenly. “Flocs” of anaerobic bacteria tend to settle against moderate flow velocities. The influent passes upward through, and helps to suspend, a blanket of anaerobic sludge. Particulate matter is trapped as it passes upward through the sludge blanket, where it is retained and digested. Digestion of the particulate matter retained in the sludge blanket and breakdown of soluble organic material generates gas and relatively small amounts of new sludge. The rising gas bubbles help to mix the substrate with the anaerobic biomass.

The major advantage of UASB over the activated sludge process is low capital and operating costs. In addition, the amount of sludge generated is much less and methane-rich biogas is generated that it may be economical to utilize as fuel for large scale facilities (>100,000 population equivalent). However, the major disadvantages are that the optimal reactor temperature is 20^{o}C or above (which may not be achievable in some areas in cold seasons), and additional treatment is required to meet secondary quality standards in terms of oxygen-consuming substances; methanogenic activity may be inhibited from the toxic effects of high concentrations of heavy metals, toxic organics, free ammonia (>50 mg/L) and free H_2S (> 250 mg/L); and chemical buffering may be required to maintain alkalinity in the reactor (Alearts et al. 1991).

c. UASB with post treatment

UASB followed by a polishing pond has been widely adopted as a method for treatment of sewage to achieve effluent discharge standards of 30 mg/L BOD and 50 mg/L SS, because of its low operational costs and good resource recovery in the form of biogas, excess sludge that can be used as fertilizer, and effluent rich in nutrients.

The use of a polishing pond with a one-day retention time requires an additional large area of land, which can be a constraint where land availability is limited. To address this problem , a new technology called the Downflow Hanging Sponge (DHS) Bio-tower has been tried out on a pilot scale in India for UASB effluent post-treatment. The technology was developed at Nagaoka University in Japan and has a unique design concept. The effluent from the UASB reactor is trickled through a curtain of sponge cubes linked diagonally and hanging in air. The sponge acts as a biomass immobilizer for attached growth. Active immobilized biomass consumes nutrients from the wastewater stream and simultaneously takes up dissolved oxygen, which naturally diffuses from air. Therefore, the most important feature of the Bio-tower is that it does not require external aeration and it can maintain a very long sludge/solids retention time (SRT).

A pilot Bio-tower of 1 MLd capacity was constructed at the 40-MLd UASB sewage-treatment plant at Karnal and has been in operation since April 2002. The Ministry of Environment and Forests reports that the performance of the bio-tower has been quite good, with the effluent having BOD of around 10 mg/L, SS of 10 mg/L, and fecal coliform of around 3,000 MPN/100 ml. The land requirement of the DHS Bio-tower is only one-tenth of the land requirement for a one-day final polishing pond (Ministry of Environment and Forests 2002).

d. Case study: Mirzapur 14 MLd UASB treatment plant[5]

The city of Mirzapur in India has a population of about 130,000. The plant consists of advanced primary treatment in UASB reactors and post-treatment in a polishing pond with retention time of one day. The current flow into the treatment plant is about 10 MLd and is projected to increase to 14 MLd by the year 2006 and to about 20 MLd by 2021. The construction plan called for a 14 MLd peak capacity plant with expansion capability to add reactor modules and pond space to reach the 20 MLd target. The inlet chamber of the plant receives raw wastewater through a 700 mm-diameter main from a pumping station. Two parallel grit traps operate in tandem on a two-day cycle of manual cleaning. The surface-loading rate of the grit traps is 45 m/h. The UASB reactor is comprised of two 2,400 m^3 units designed for an organic loading rate for chemical oxygen demand (COD) as volatile solids of 0.3 $kg/day/m^3$ of reactor capacity. The minimum height of the sludge blanket is two meters, and the average hydraulic retention time (HRT) is about eight hours. The sludge-settling compartment of the gas/liquids/solids phase separator is designed to accommodate a maximum surface-loading rate of 2 m^3/m^2/hour.

Gas production is in the order of 500 m^3/day based on a gas yield of 0.1–0.15 m^3/kg of COD removed. The gas composition is about 80 percent methane, with potential to produce 70 kW of electric power. Because the daily power requirement of the plant is 12 kW, two dual-fuel generator sets of 18 kW are provided. Excess anaerobic sludge is produced at the rate of 0.2 kg of total suspended solids per m^3 of treated effluent and is withdrawn regularly and dewatered on sludge-drying beds that have a total area of 2,000 m^2. The loading rate on the drying beds is 520 kg/m^2 of total solids per year, with a drying time of seven days. The dried sludge is removed manually and sold to farmers as a soil conditioner. Table 7 presents the average removal rates and the average quality of the influent, reactor effluent, and final effluent of the Mirzapur treatment plant.

Table 7. Mirzapur 14 MLd UASB plant average influent and effluent quality and removal rates

Parameter (averages)	Influent (mg/L)	Effluent (mg/L)	Removal rates (%)	
			Reactor effluent	Final effluent
COD	411	160	61	81
BOD_5	193	50	74	84
Total suspended solids	360	108	70	87

Source: Journey and McNiven 1996.

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[5] This case study is based on Journey and McNiven 1996, with minor alterations.

e. Small-scale urban/peri-urban

In most Asian cities, peri-urban areas are not yet equipped with wastewater-treatment facilities. This offers the possibility to look for decentralized solutions involving new, more-efficient biological treatment processes, local management, nutrient recycling, energy recovery, and combined management of treated effluents and storm water. In this way, trunk sewers and pumping of wastewater over long distances can be avoided and water resources locally administered and used. Integrated recycling can be the common ground for the systems to be suggested in the peri-urban context (US Environmental Protection Agency 1992). Also, building traditional-style centralized sewerage systems and treatment plants is expensive. Table 8 shows that the capital costs even in low-income countries—where labor and material costs are low—conventional wastewater treatment plants cost several times more than on-site systems (for example, septic tanks). While the average costs for capital, operation, and maintenance on a per capita basis appear to be low for centralized systems, a considerable portion of urban families of developing countries cannot afford even on-site options. There is hence a need to find innovative or alternative solutions to meet the needs of a sizeable portion of the urban population in developing countries.

Table 8. Cost range per capita of on-site and sewered options with conventional treatment

Economy type	Option	Capital cost (US$/capita)	Total cost[1] (US$/capita/year)
Low-income economies	On-site sanitation	10–100	3–10
	Treatment plant	20–80	5–15
	Sewer plus treatment plant	200–400	10–40
Middle-income and transitional economies	Treatment plant	60–80,[2] 30–50[3]	–
	Sewer plus treatment plant	300–500[3]	30–60[4]
Industrialized economies	Treatment plant	150–300[2], 100–200[3]	–
	Sewer plus treatment plant	–	100–150[4]

1. Total cost includes capital and O&M costs.
2. For primary plus secondary treatment, including land purchase and simple sludge treatment for capacity of 30,000–40,000 persons. Lower values pertain to low-cost option, such as stabilization ponds; higher values pertain to mechanized treatment, such as oxidation ditches and activated sludge plants.
3. For plant capacity equivalent to 100,000–250,000 persons.
4. For industrialized countries, this includes tertiary treatment and full sludge treatment; for other countries this includes basic secondary treatment.

Source: UNEP 2002.

There are options among several basic systems of conventional treatment systems that vary in cost depending on the level of treatment and availability of space. The Japanese Johkasou system, though not a new development, offera solutions for small to medium-sized communities from several up to tens of thousands of households. The innovation is in how this tested system can be built with minimal costs using local materials and labor and, for example, the use of excavated material for laying pipes.

7. Incentives and technologies for wastewater reuse

Some parts of the East Asian region suffer from low precipitation and periodic or seasonal drought. Conventional sewage-treatment systems using water-based technologies do not operate effectively when water is short. Solutions need to be found for such areas, especially as pollution from untreated sewage is exacerbated by small or non-existent flow of water in streams and rivers. Reuse of wastewater holds a lot of promise for such conditions.[6]

Reuse of treated or untreated wastewater has the following benefits: it increases water supplies by reducing demand for higher-quality water; it reduces wastewater discharge, thus reducing water pollution; and it is economically efficient as it means lower water costs compared to transporting water from distant sources.

In water-short cities and “green buildings”, recycled water is used for cleaning purposes and for flushing toilets. Similarly, it is used for cooling, cleaning, and dilution in industrial plants, but separate pipeline systems are required for both uses (Ogoshi, Suzuki, and Asano 2001). However, excessive silt can block pipelines and requires more expenditure on maintenance. An innovation is the processing of wastewater into ultra-clean water using new filtration technology. There is now such a plant in Singapore, and the water from it can be used for special industrial purposes that require water with a high degree of purity. Recharging of groundwater with treated or untreated water in water-scarce areas and in cities in danger of depletion of groundwater leading to soil subsidence is a matter of considerable interest. Perhaps other innovative uses could be explored and tried within the region.

Most Asia-Pacific countries are tropical and their water resources are relatively abundant. As a result, most of the developing countries in this region do not reuse wastewater. Exceptions are India, China, and Vietnam, where wastewater is being used for irrigation (Shuval 1990). Reuse of wastewater occurs most effectively with on-site or small-scale treatment systems. Thus, implementation of reuse options in local contexts with local community consultation must be seriously considered.

In India, studies on agricultural productivity have found that recycling and reuse of nutrients and other valuable materials in domestic and industrial wastewater is effective . General utilization of wastewater through reuse and recycling has become very important. In fact, wastewater is recognized as a resource rather than a burden since it contains appreciable amounts of nitrogen, phosphorus, and potassium. Stabilization ponds can be used for fish aquaculture and the effluent can be used for cultivation of short-term and long-term ornamental, commercial, and fodder crops (UNEP 2002).

Wastewater has been adopted as one of the major water resources nationwide in China, especially in the northern area of coastal cities. The main potential applications for reuse of treated wastewater in China are in the following fields:

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[6] The first and third paragraphs of this section are based on Chia 2001b, with minor alterations.

- Agricultural use through irrigation of crops as well as for improving river amenity;
- Industrial cooling, especially in large industrial enterprises;
- Reuse in municipal public areas, such as watering lawns and trees;
- Flushing toilets in hotels and residential districts; and
- Reuse of the treated wastewater for urban landscaping purposes.

Many municipalities set wastewater reuse as a strategy to meet increasing water demand. To identify the alternatives of wastewater reuse as well as their feasibility and implementation, some cities where water shortages and pollution are very serious problems, such as Beijing, Tianjin, Taiyuan, Dailian, and Qingtao, have been selected as pilot areas for this purpose.

Treatment and reuse of the wastewater from a guesthouse in Jinan city in Shandon Province is an example of reuse of treated wastewater for non-potable purposes in a water-short area. The wastewater is first given rotating disc biological treatment followed by filtration and disinfection. The treated wastewater is reused for watering grass, maintaining water level in a lake, washing cars, and flushing toilets. In another example, a wastewater treatment plant with a capacity of 50,000 m^3/day was built in Tai Yuan City, Shanxi Province from which 20,000 m^3/day is reused for industrial cooling and landscaping purposes after reclamation by tertiary treatment. By 2000, more than 20 percent of total discharged wastewater in municipal areas of China was treated, and 10 percent of treated wastewater was reused (UNEP 2002) .

8. Uses for excrement and sludge

There are valuable nutrients in human (and animal) excrement that for centuries have been used directly as fertilizers and soil conditioners for growing vegetables and horticulture as well as to fertilize fishponds (Chia 2001a; Fauziah and Rosenani 1996). This practice has, however, been the cause of many waterborne diseases that constitute a major health hazard in many countries. Sludge biogas reactors, designed for village-scale use, have been in existence for a long time in China, Vietnam, and elsewhere. In the construction industry, sludge is also used to make pavement bricks and other building materials. One of the most promising technologies is sludge composting.[7]

The recycling of sludge arising from wastewater treatment is to be encouraged, and disposal of sludge to surface waters should be phased out. It is necessary to monitor treatment plants, receiving waters and the disposal of sludge to ensure that the environment is protected from the adverse effects of the discharge of waste waters (European Economic Community 1991). It is also important to ensure that information on the disposal of wastewater and sludge is made available to the public in the form of periodic reports.

9. Graywater and blackwater separation

Graywater is wastewater from showers, sinks, washing machines, and similar sources, while blackwater is wastewater specifically from toilets. It is not necessary to mix graywater and blackwater.

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[7] This paragraph is based on Chia 2001b, with minor alterations.

Because it contains far less organic material than blackwater, graywater does not require the same treatment process. By designing plumbing systems to separate it from blackwater, graywater can be recycled for irrigation, toilets, and exterior washing, resulting in water conservation. Also, graywater decomposes much faster than does blackwater; therefore, if graywater is injected into bio-active soil near the surface, groundwater is better protected from organic pollution than it would be if combined graywater and blackwater were injected, since the treatment takes place rapidly in the soil and is practically finished two to three feet below the surface. Graywater contains only one-tenth of the nitrogen contained in blackwater. Nitrogen (in the form of nitrites and nitrates) is the most serious and difficult-to-remove pollutant affecting drinking water. Furthermore, the nitrogen found in graywater is around half organic nitrogen (that is, tied to organic matter) and can be filtered out and used by plants (Lindstrom 2000). Blackwater can be diverted from wastewater systems by introducing non-flushing toilets. This should be considered especially in water-short suburban areas as it can reduce water use and establish new nutrient cycles between urban areas and agricultural regions.

10. Urine separation

Blackwater can by further broken down by separating urine from faeces. From urine, a nutritious fertilizer can be obtained and groundwater, lakes, and sea can be protected from over-fertilization, which leads to eutrophication, which can increase algal growth and in turn lead to lack of oxygen in the water, causing seabed fauna to die and fish to migrate away. From traditional water-closet sewage, it is possible to retrieve about 98 percent of the nitrogen, 68 percent of the phosphorous, and 85 percent of the potassium in urine. These nutrients are in the perfect composition to be taken up by plants. Spreading the urine on farmlands also reduces the need for artificial fertilizers (Verna Ecology 2001). Urine-separating toilets differ from standard toilets in that they have a bowl in the front for urine, with the faeces going to the rear. In the majority, the forward bowl is flushed to a storage tank using a small quantity of water. The faeces either are flushed to a sewage-treatment system or are composted, with no contact with water at all, for use in plant cultivation.

11. Industrial waste prevention

Industrial wastewater entering collecting systems, and discharge of wastewater and disposal of sludge from urban wastewater treatment plants, should be regulated. Industrial wastewater entering collecting systems and urban wastewater treatment plants should be subjected to pre-treatment in order to:

- Protect the health of staff working in collecting systems and treatment plants;
- Ensure that collecting systems, treatment plants, and associated equipment are not damaged;
- Ensure that the operation of wastewater treatment plants and treatment of sludge are not impeded;
- Ensure that discharge from treatment plants does not adversely affect the environment, including the water bodies into which it is discharged; and
- Ensure that sludge can be disposed of safety in an environmentally acceptable manner (European Economic Community 1991).

One possible solution for industrial waste treatment is the common effluent treatment plant (CETP) for several small-scale and medium-scale industries. Under the World Bank-aided Industrial Pollution Control Project there is a provision of loan and grant assistance to proposals of construction of CETPs for the treatment of effluents from a cluster of industries, particularly small-scale industries (Central Pollution Control Board 1999).

At present, there are 18 CETP sites for tannery clusters in five districts of Tamil Nadu, India. Out of these, 11 CETPs are in operation and the rest are under construction.

12. Conclusions

There is much work to do to make wastewater management sustainable in the rapidly growing cities of developing Asia. However, experience and innovation from around world offer a range of solutions to the existing problems, if only the resources and, more importantly, the political will can be found. The first major observation is that governments need to take a watershed approach while planning wastewater management in urban areas. It helps in identifying the most cost-effective pollution-control strategies to meet clean water goals. For major cities with highly populated areas, large centralized sewerage systems are generally the most efficient and are sometimes even essential, with advanced wastewater-treatment facilities for nutrient reduction and possible reuse. For medium-scale cities with limited resources and funding, simple treatment technologies with lower O&M costs have been found to be very promising. For peri-urban areas and small cities, decentralized systems are very suitable. In addition, certain new concepts of sanitation should be considered as these can have multiple benefits, both economic and environmental. Nutrients in wastewater can be captured and reused in agriculture by separating urine, graywater, and blackwater, or by simple use of sludge as fertilizer. Reuse of wastewater in a variety of applications can significantly reduce the need for fresh water, reducing the demands urban areas make on the surrounding environment and mitigating water shortages in dry and semi-arid areas. Clearly there are many options available that might help to make wastewater treatment more sustainable. An exchange of views, scientific data, and practices to compare experiences would yield invaluable insights into better ways of managing urban wastewater in Asia.

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