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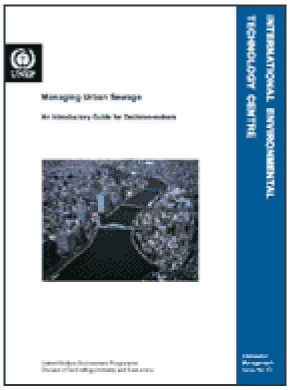
Managing Urban Sewage
An Introductory Guide for Decision-makers



This document is part of the IETC series of Introductory Guides for Decision-makers. These guides are intended to assist decision-makers at the local level in understanding the issues and making informed decisions for the benefit of all citizens and stakeholders.

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I. Introduction

This document is part of the IETC series of Introductory Guides for Decision-makers. These guides are intended to assist decision-makers at the local level in understanding the issues and making informed decisions for the benefit of all citizens and stakeholders. It should be noted that this document does not address a number of critical issues that ultimately influence decisions related to urban sewage treatment, including:

- Options for citizens to reduce waste and minimize discharges to the sewage system;
- Potential application of smaller scale, decentralized treatment facilities and infrastructure;
- Land application of biosolids;
- Specific construction methods, such as those used for the installation and maintenance of underground sewage pipelines.

It is also important to note that the effectiveness of the overall system is based upon a sound regulatory framework, coupled with ongoing testing and evaluation.

II. The Importance of Managing Sewage

The scope of sewage management has evolved throughout history with changes in socioeconomic conditions, city structures, and the environment. Today, sewage infrastructure that is well planned and operated supports urban sanitation and related activities. Effective sewage management is essential for nutrient recycling and for maintaining ecosystem integrity. It is also important for:

- Improving the environment through proper drainage and disposal of wastewater;
- Preventing floods through removal of rainwater;
- Preserving receiving water quality.

The sewage treatment process facilitates the achievement of water quality objectives. In addition to nutrient recycling, advanced treatment of wastewater often includes associated unit processes which support the optimization of resource use. Some of these unit processes include the conversion of sludge into various beneficial by-products, and the process of extracting thermal energy from sewage and wastewater. In addition, the sewage collection system can be used as a conduit for optical fibre cables and other communications infrastructure.

A. Sewage Works Planning and Administration

Sewage works should be planned and executed by municipalities in collaboration with other levels of government. The authority for the construction and management of treatment plants, trunk sewers and branch collectors varies depending upon the jurisdictional arrangements in a given country. In the City of Tokyo for example, sewage treatment and the provision of trunk sewers for the City's 23 ward areas is carried out by the Metropolitan Government. The Metropolitan Government carries out the construction and management of these facilities within the regional sewage system, while the municipalities themselves are responsible for connecting the branch sewers with the trunk sewers.

B. Water Recycling Master Plans

Some cities have established a water recycling master plan to ensure the efficient use of precious water resources. Under such a plan, water-related measures are examined from the viewpoint of water recycling and all activities within the city are carried out in a manner consistent with the master plan. The objectives of a water recycling master plan should include the creation and nurturing of a water cycle that has a minimal impact on the environment while fostering a beneficial relationship between humans and nature. This involves the establishment of an efficient water and wastewater systems within the city and ensuring sufficient flexibility to cope with the possibility of environmental emergencies and possible disasters such as earthquakes and drought.

III. Sewage Facilities

A. Sewage Collection

There are two types of sewage collection systems - combined and separate. Combined sewers carry away both rainwater and wastewater, while separate sewers take care of wastewater and rainwater in separate pipes. Combined sewage collection systems are often used because the cost of construction is less than that of a separate system. In a combined sewage collection system, the rainwater mixed with wastewater is allowed to flow directly into rivers and adjacent water bodies during wet weather conditions. In a separate sewage collection system, rainwater mixing with wastewater is minimal, but the problem of pollutants on road surfaces being carried into rivers and coastal waters still exists. The construction of a separate sewage collection system is relatively expensive and more complex due to the need to install two sets of pipes.

B. Pumping Stations

Wastewater collected by the sewers flows by gravity and is relayed to treatment plants by pumping stations. In flat land, sewers tend to be laid deeper and pumping stations must be used to lift the sewage closer to the surface where it can be treated in a sewage treatment plant. Pumping stations often have both wastewater and rainwater pumping facilities. Where this is the case, the rainwater is usually pumped into subsurface aquifers below sea level or into the sea directly to prevent inundation of rivers and surface waters.

C. Wastewater Treatment Plants

The principal role of a wastewater treatment plant is to remove pollutants from wastewater and to discharge the treated effluent into an adjacent waterbody such as a river or the sea. Treatment plants can be divided into discrete unit processes as outlined below.

- *Grit Chamber* - Within a wastewater treatment plant, raw wastewater first enters a grit chamber. As the wastewater flows gently through the chamber, solids (such as sand, grit and gravel) settle to the bottom, and are removed by buckets, while large suspended matter is removed by screens. The wastewater is then pumped into a primary sedimentation tank.
- *Primary Sedimentation Tank* - As the wastewater flows slowly in a primary sedimentation tank for two to three hours, organic solids gradually settle to the bottom. This mass of solids is called raw sludge, and is sent to a sludge treatment facility for further treatment. To make the most of available land, double-decker sedimentation tanks are used at some wastewater treatment plants.
- *Aeration Tank* - The major role of the aeration tank is to remove the soluble organic material that escaped treatment in the primary sedimentation tank and to provide further removal of suspended solids. In order to ensure the sufficient and rapid decomposition of organic material, it is necessary to promote the growth of microorganisms capable of absorbing these soluble organic materials. In the activated sludge process, the aeration tank mixes and agitates wastewater and activated sludge. During the 6 to 8- hour aeration period, the microorganisms absorb the organic matter as nutrients, and they grow as a result. This decomposes the organic matter into inorganic substances such as water and carbonic acid gas. The suspended solids adhere to microorganisms and then form clots that can be easily removed as sediment.
- Activated sludge contains a large quantity of microorganisms and is based on the same principle as nature's process of purifying water. The activated sludge process involves putting activated sludge into wastewater and decomposing organic matter into such inorganic substances as water and carbon dioxide through the metabolic activity of the microorganisms.
- *Secondary Sedimentation Tank* - While the mixture from the aeration tank flows slowly in a secondary sedimentation tank, it is separated into solids (activated sludge) and an aqueous portion (or supernatant). Part of the activated sludge is returned to the aeration tank, and the rest is treated in a sludge treatment facility. The secondary effluent is usually discharged into the receiving environment after chlorination. Following advanced treatment, part of the sewage treatment plant

effluent is often used for miscellaneous purposes in the plant and as water for toilets in buildings. In addition, it can be used to augment the flow of smaller streams. In some cities such a Tokyo, double-decker secondary sedimentation tanks are used to make more effective use of available land.

- *Sludge Treatment* - The raw sludge from the primary sedimentation tank and the excess sludge are pumped to thickening tanks. In the thickening tank, the volume of the sludge is reduced to about one-quarter of the volume of the raw sludge. The thickened sludge is then mechanically dehydrated. The sludge is sometimes sent to a digestion tank after being thickened. There are different types of sludge drying (or dehydrating) machines, including vacuum, centrifugal, filter press, and belt press. Dehydrated sludge is often burned and becomes ash. The ash generated by incinerating sludge is usually about 1% of the original sludge volume.

IV. Construction

Sewage infrastructure construction work includes the installation of the sewage collection system, engineering and construction of pumping stations and wastewater treatment plants, and the installation of a wide range of machinery and electrical equipment for pumping stations and wastewater treatment plants. Sewage infrastructure construction in urban areas involves a number of considerations as discussed below.

A. Underground Obstacles

In most cities, underground space is highly utilized, and it is necessary to take into account proximity to other underground facilities as subways, waterworks, electric power cables, gas pipes and telephone lines. Special construction methods to move, reroute or undertake work in close proximity to water and gas mains is sometimes required. Making adjustments in consultation with those who manage underground facilities is time consuming and as a result an extended construction period or additional costs can arise.

B. Space for Facilities and Construction Work

The construction of facilities such as treatment plants and pumping stations requires a large amount of space. Driving shafts for base construction and for burying large sewer pipes also requires space. Most cities use public land such as parks, or purchase or lease private land to secure sufficient space. It is often difficult to obtain consent from land owners, and negotiations can require a significant amount of time. Securing land can interfere with other public works projects such as the construction or expansion of roads and the improvements of rivers and waterways.

C. Disposal of Soil from Construction Projects

Soil generated from construction projects can be a problem and planning is necessary to identify ways of reusing this soil or reducing the amount of soil generated.

D. Obtaining the Understanding and Cooperation of Stakeholders

Experience has shown that sewage construction projects should incorporate an ISO 14001 environmental management system. Equipment and processes should be selected to minimize noise and vibration which can be irritants to local residents. It is also important to hold information meetings to obtain the support of residents. This is necessary for both sewage construction projects and the refurbishment of older sewers.

V. Operation and Maintenance

Sewage facilities must operate under severe conditions created by the constant flow of highly corrosive wastewater and have to continuously pump and treat wastewater on a 24-hour basis. To ensure the provision of safe and reliable services, it is necessary to operate and maintain these facilities in an efficient manner.

A. Sewers

Since most sewer mains and pipelines are located under roads, they are affected by external factors such as loads and vibrations caused by traffic as well as the settling or sinking of ground, often resulting in breakage or cracking of pipes. For this reason, regular inspections, cleaning and repair work are essential for maintenance. In addition to constant surveillance, systematic inspections are carried out to ensure that damage is detected at an early stage and that repairs are made. To maintain the flow and capacity of the system, cleaning is performed on a regular basis. Care must also be taken to ensure that damage identified during monitoring or cleaning does not lead to a future accident or system failure.

To ensure that sewer mains and pipelines are properly operated and that their status is clearly understood, data relating to sewer mains, pipes and soil chambers should be collected and recorded using a sewage ledger system. This can help facilitate improved preventative operation and maintenance, allowing damage to be identified sufficiently in advance to prevent the occurrence of accidents. Furthermore, by adopting new techniques, such as nondestructive inspection, operational costs can be reduced.

B. Pumping Stations

When heavy rain occurs, pumping stations must quickly drain away rainwater runoff that rushes into the sewers and discharge it into the sea, adjacent rivers, or underground. Pumping stations are often unmanned and remotely controlled or monitored by master pumping stations, however they must be operated continuously and maintained, since swift operation is essential.

C. Wastewater Treatment Plants

The operation and maintenance of a wastewater treatment plant is complex and requires trained operators and sufficient financial resources to ensure that these facilities continue to operate in an acceptable manner. The volume of wastewater requiring treatment in a large city can be substantial. For example, in Tokyo, the amount of wastewater treated in 1999 was on average 4,740,000 cubic meters a day, and the amount of sludge treated was on average 154,330 cubic meters a day.

VI. Information Systems

Information systems and other knowledge management tools can help improve the efficiency and reliability of urban sewage infrastructure. Some examples are described below.

A. Rainfall Information Systems

Some cities have established rainfall information systems to protect residents from floods. These systems are based upon the electric waves emitted from radar and reflected by raindrops and identify areas of rainfall and intensity. This information is then sent to pumping stations, sewage system maintenance offices and treatment plants to allow adequate time for staff to prepare and to ensure immediate pump operation. Data can also be collected and processed at a central information processing facility.

B. Sewage Mapping and Data Management Systems

It is also important to obtain accurate information on sewage facilities in order to maintain and manage them effectively. In Tokyo, a sewage mapping and information system, SEMIS, was installed in April 1986. SEMIS has allowed Tokyo to systematize its sewage facility information and create a database for operational purposes.

VII. Addressing Local Environmental Issues

A. Enhancing Green Space and Recreational Opportunities

In the case of sewage facilities near residential or commercial areas, ensuring harmony with the surrounding environment is important. In areas adjacent to wastewater treatment plants, the integration of green space within the local ecosystem is an important objective. In some cities, green space and recreational facilities have been established on the roofs of pumping stations and wastewater treatment plants.

B. Preventing Odours and Emissions

It is also necessary to take measures to prevent odours and smoke from affecting the comfort of residents in areas near sewage facilities. One measure of confining odour is to contain diffusion of vapours and gases produced during the sewage treatment process. Another technique is to deodorize foul-smelling substances by chemical washing, activated carbon absorption, use of microorganisms, or incineration. A catalytic oxidation process can be used to mitigate exhaust fumes, including nitrogen and sulfur oxides that arise from the sludge incineration process.

C. Improving the Performance of Combined Sewer Systems (CSOs)

In a combined sewer system, both rainwater and wastewater are conveyed in the same conduit during wet weather, and part of this is discharged into the receiving waters without treatment. This poses a serious problem in protecting water quality. For this reason, some cities have adopted an interceptor strategy to increase the volume of wastewater that is treated. In some cases, a CSO storage tank is installed to prevent polluted first flush from flowing into the receiving water in the early stage of rainfall. In addition, screens can be installed to prevent rubbish from flowing from the rainwater outlets into natural drainage areas.

D. Flood Control

In some cities, the sewage system is used for flood control. However, even in areas with sewers, floods can occur. The cause is often dense clusters of buildings and paved areas arising from urbanization. As a result, rainwater is unable to infiltrate the ground, and large amounts of rainwater exceeding sewer capacity accumulates and overflows. The resulting flooding is referred to as "urban flooding". In order to improve the capacity of sewage facilities to cope with these conditions, various countermeasures against flooding can be undertaken, including:

- Augmenting the capacity of sewers and pumping stations and constructing rainwater storage tanks in areas where the rainwater runoff exceeds the capacity of existing sewers.
- Promoting the installation of rainwater storage and infiltration facilities to control the inflow of rainwater into sewers.

VIII. Optimizing Resource Efficiency

A. Utilization of Reclaimed Water

One of the key policies now being considered by many cities is to optimize the use of abundant, high-quality effluent from treatment plants, recognizing that this is an important water resource. For example, in 1984, a water recycling centre was established in Tokyo to provide water recycling services using rapid sand filtration and chlorination to produce a recycled effluent for toilet flushing in 25 high-rise buildings. The recycled water in this application is charged at a rate lower than that for conventional city water. Area-wide recycling using advanced wastewater treatment is an option that can be considered in areas where large-scale urban development projects are planned.

B. Utilization of Sludge

There are a number of useful by-products that can be derived from municipal sewage sludge, including:

- Concrete products made from sludge ash, such as reinforced-concrete pipes
- Lightweight aggregate made from sludge ash to replace natural aggregate used in water-permeable bricks and building construction materials
- Compressed baked blocks, based on press and burn technology whereby the pressed molded sludge ash is burned at a temperature of about 1050 degrees Celsius to manufacture durable interlocking bricks that it can be used as for pavement and park landscaping.
- Sludge melted slag where the sludge is heated up to 1500 °C, the organic matter is decomposed and burnt, and the remaining inorganic matter is melted to a liquid state. When cooled and solidified, this melted inorganic matter, referred to as sludge melted slag, has half the volume of sludge ash and is highly stable with no dissolution of heavy metals contained in the slag. Several uses for sludge melted slag have been investigated, including its use in road bed or construction materials.

All of these applications make use of a valuable resource that would otherwise be wasted.

C. Utilization of Wastewater Heat

In most cities, the temperature wastewater is lower in summer and higher in winter than the ambient atmospheric temperature. This characteristic of wastewater can be used as a heat source for cooling and heating which can contribute to energy savings and associated reductions in air pollution. Since the use of wastewater for heating and cooling does not involve the construction of a cooling tower, it is also serves as a way of avoiding unnecessary noise.

D. Pretreatment Requirements for Industrial Wastewater

To preserve both the function and physical structure of the public sewer system, as well as to ensure the quality of the water that runs through public water bodies, factories and other establishments should not permitted to directly pump wastewater containing toxic substances into the public sewer system. Before discharging wastewater into the system, these stakeholders should be required to treat the wastewater so that it conforms with predetermined water quality standards (sewage effluent standards).

In some cities, sewer use bylaws and ordinances have been developed prohibiting factories and businesses using the public sewer system from discharging wastewater that does not satisfy acceptable pretreatment standards. In most of these cities, the local sewage department provides guidance for appropriate wastewater quality control, monitors the wastewater pretreatment systems of factories and businesses, by conducting regular performance inspections.

It should also be noted that the pre-treatment of some industrial effluents can provide significant economic benefits as a result of resource recovery and reuse.

E. Finance

The ongoing financing of sewage infrastructure is a significant challenge. In most cities, a local public utility is responsible for the establishment of a financial accounting system. By separating capital accounting from revenue accounting, the local utility is able to analyze the effectiveness of management and promote incremental improvement in the operation of the system.

In most cities, the sources of revenue for the construction of sewage facilities are often national subsidies, bonds, and funds appropriated from general tax revenues. In some cases, national subsidies are provided for the construction of pumping stations, trunk sewers, and treatment plants. In addition to national subsidies, a major portion of the capital expenditure is paid by bonds and other long term borrowing of funds, with the remainder of the funds coming from revenues derived as income obtained from user fees. The main items of revenue expenditure are maintenance and management, depreciation and interest payments. Although expenditures on wastewater treatment are usually paid by users in the form of service charges, expenditures on stormwater runoff are usually supported by general tax revenues.

Annex I

How Sewage Treatment Works (PDF)

Bureau of Sewerage, Tokyo Metropolitan Government

The construction of modern sewerage in Tokyo dates back to 1884, when a horseshoe-shaped bricklaying sewer was installed in the downtown area named Kanda, a part of the pipe is stillin use and is monumentally called the "Kanda Sewer".

Some 110 years after the Kanda Sewer was laid, the sewerage system in the ward area, which is the metropolis area, provided service to almost 100% of the population by the end of March 1995. And the regional sewerage system in suburban Tokyo area, "Tama area" covered 93% of the population by the end of March 2002.

There are thirteen treatment plants in the ward area, which receive approx. 4.6 million tons of wastewater every day, and seven plants in "Tama area" receive approx. 0.86 million tons.

The role of sewerage in Tokyo has changed and expanded in scope from age to age with changes in socioeconomic conditions, metropolis structures, and the environment.

Its fundamental roles at present are:

(1) Improving the living environment by drainage and disposal of wastewater;
(2) Preventing inundations through removal of rainwater;
(3) Preserving the quality of public water bodies.

And also, sewerage performs many other roles. It enhances water environment through recycling and advanced treatment of wastewater, conversion of sludge into resources, thermal energy is extracted from sewerage by such methods as tapping the heat in wastewater, and optical fiber communication cable channels are furnished.

In addition to these, Bureau of Sewerage, T.M.G. is carrying out the following projects as priorities to implement a desirable sewerage system in the 21st century.

(1) Reconstruction; Part of Tokyo's sewers has deteriorated due to aging and external physical disturbance such as unexpectedly heavy traffic above, ground subsidence, and so on. At present, the length of the sewers, which have exceeded legal service life, is about 2,000km and this number will continue to grow in future. Also, some plants have difficulties to cope with the increase of the flow of wastewater and rainwater due to improvements in living standards and land use. Therefore, reconstruction has been promoted by rehabilitating the deteriorated facilities, increasing the insufficient capacities, and upgrading of functionability.
(2) Inundation Control; In recent years, inundation has occurred even in sewered urban areas. The cause is the fact that the land surface is covered with buildings, pavement and other structures. As a result, rainwater does not infiltrate to the ground and large amounts of rainwater that exceed sewer' capacity runs off and overflows. In order to prevent the inundation, the capacity of sewers and pumping stations needs to be augmented and the construction of rainwater storage tanks is necessary.
(3) Improvement of combined sewer system; In the combined sewer system, which serves 82% of the total area, both rainwater and wastewater runs in the same pipe during wet weather, and in case of heavy rain, part of this overflows into the receiving waters without treatment. This is called "CSO" and poses a serious problem in preserving the water quality of public water bodies. Expansion of CSO intercepting sewers to wastewater treatment plants and installation of CSO storage tanks are being

implemented for the countermeasures.

Bureau of Sewerage, T.M.G. obtained ISO14001 "the Environmental Management System" certification in its all departments and offices by December 2002. Bureau of Sewerage, T.M.G. is dedicated to create desirable water environment in Tokyo and transfer it to future generations through the daily activities stated above.

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About the UNEP Division of Technology, Industry and Economics

The mission of the UNEP Division of Technology, Industry and Economics is to help decision-makers in government, local authorities, and industry develop and adopt policies and practices that:

- are cleaner and safer;
- make efficient use of natural resources;
- ensure adequate management of chemicals;
- incorporate environmental costs;
- reduce pollution and risks for humans and the environment.

The UNEP Division of Technology, Industry and Economics (UNEP DTIE), with the Division Office in Paris, is **composed of one centre and five branches:**

The International Environmental Technology Centre (Osaka), which promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins, in developing countries and countries in transition.

Production and Consumption (Paris), which fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

Chemicals (Geneva), which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety world-wide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).

Energy and OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of the Unit.

Economics and Trade (Geneva), which promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

Coordination of Regional Activities Branch, which coordinates regional delivery of UNEP DTIE's activities and ensures coordination of DTIE's activities funded by the Global Environment Facility(GEF).

UNEP DTIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

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The UNEP - DTIE International Environmental Technology Centre

Established in April 1994, the International Environmental Technology Centre (IETC) is an integral part of the Division of Technology, Industry and Economics (DTIE) of the United Nations Environment Programme (UNEP). It has offices at two locations in Japan - Osaka and Shiga.

The Centre's main function is to promote the application of Environmentally Sound Technologies (ESTs) in developing countries and countries with economies in transition. IETC pays specific attention to urban problems, such as sewage, air pollution, solid waste, noise, and to the management of fresh water basins.

IETC is supported in its operations by two Japanese foundations: The Global Environment Centre Foundation (GEC), which is based in Osaka and handles urban environmental problems; and the International Lake Environment Committee Foundation (ILEC), which is located in Shiga Prefecture and contributes accumulated knowledge on sustainable management of fresh water resources.

IETC's mandate is based on Agenda 21, which came out of the UNCED process. Consequently IETC pursues a result-oriented work plan revolving around three issues, namely: (1) Improving access to information on ESTs; (2) Fostering technology cooperation, partnerships, adoption and use of ESTs; and (3) Building endogenous capacity.

IETC has secured specific results that have established it as a Centre of Excellence in its areas of speciality. Its products include: an overview on existing information sources for ESTs; a database of information on ESTs; a regular newsletter, a technical publication series and other media materials creating public awareness and disseminating information on ESTs; Local Agenda 21 documents developed for selected cities in collaboration with the UNCHS (Habitat)/UNEP Sustainable Cities Programme (SCP); advisory services; Action Plans for sustainable management of selected lake/reservoir basins; training needs assessment surveys in the field of decisionmaking on technology transfer and management of ESTs; design and implementation of pilot training programmes for adoption, application and operation of ESTs; training materials for technology management of large cities and fresh water basins; and others.

The Centre coordinates its activities with substantive organisations within the UN system. IETC also seeks partnerships with international and bilateral finance institutions, technical assistance organisations, the private, academic and non-governmental sectors, foundations and corporations.

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