WASTEWATER MANAGEMENT ENGINEERING

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Contents

Summary

General schemes of wastewater and solid wastes management engineering are presented in this chapter. Firstly, a brief historical development and changes of target substances and management technologies and policies are introduced and some details of wastewater management and solid wastes management are analyzed.

A lot of water is consumed not only for daily life of the people but also for commercial, industrial, and agricultural activities. Consumption of water, however, does not necessarily mean disappearance of water itself. In many cases, consumption of water means degradation of water quality and production of wastewater contaminated with human wastes, industrial wastes, and other human activities. The discharge of wastewater into natural water bodies usually causes water pollution and thereby damage to both human health and natural ecosystems.

To abate the water pollution, the wastewater should be collected separately and treated to remove the contaminants, target substances, using various technologies based on physical, chemical, and biological principles. In the processes, the solid liquid separation is used as a very basic and common unit process and the conversion to the larger size solids is a basic concern in the treatment of wastewater.

As for the solid wastes management, the definition of waste is important. When materials possessed by persons for human activities are no longer useful and have lost their value for the owner, they are regarded as wastes. Among the wastes, the gavages from human daily life are common target substances through the world. The industrial wastes sometimes contain hazardous substances and in that case they have to be separately treated and discharged into special landfill site.

Special feature of solid wastes management is that some categories of wastes can be reusable directly or recycled for materials to be used for making new products. So the separation process at the origin of wastes is thought to be very important process in the management of the solid wastes. Although the generation of wastes is unavoidable as

long as human activity continues, it is important for sustainable development of society to minimize the generation of wastes and to appropriately dispose of or recycle generated wastes.

1. Introduction

Most of the activities of modern societies highly depend on the supply of sufficient amount of clean water. A lot of water is consumed not only for daily life of the people but also for commercial, industrial and agricultural activities. Consumption of water, however, does not necessarily mean disappearance of water itself. In many cases, consumption of water means degradation of water quality. When water is once used for some specific purpose, the water contains such compounds as carbohydrates, proteins, lipids, metals, nutrients, or microorganisms and so on. Then the water is called wastewater since such water is not clean enough for use and has to be wasted. Since the quantity and quality of wastewaters from municipal areas usually exceed the assimilative capacity of receiving natural waters, collection and treatment of wastewaters is required to keep the water resources clean enough. Water quality standards of natural waters are established for this purpose and wastewater management is carried out to achieve the water quality standards, or to sustain natural waters as sound as possible.

After the invention of modern sewerage systems in the late 19th century, various treatment methods were developed to purify wastewaters. Since sludge is produced during the course of wastewater treatment, various sludge treatment technologies were also developed. In the section of wastewater management engineering, municipal wastewater treatment and sludge treatment technologies are introduced.

Regarding solid wastes management, when materials possessed by persons for human activities are no longer useful and have lost their value for the owner, they are regarded as wastes. Such wastes may be so dirty or harmful that they contaminate the natural environment if discarded carelessly. Since the generation of wastes is unavoidable as long as human activity continues, it is important for sustainable development of society to minimize the generation of wastes and to appropriately dispose of or recycle generated wastes. In the section of solid waste management, an outline of history of waste management problems, political and technological aspects of solid wastes management, and initiatives to define the type of integrated solid waste management system in future scheme are introduced and discussed.

2. Wastewater Management

2.1. Historical Summary of Water Pollution Control

Water pollution has been an issue ever since people began to live in cities or areas of high population density. The first signs of water pollution took the form of hygiene problems resulting from the pollution of drinking water in industrialized and urbanized cities like London in England in the early 1830's. Although the knowledge about pathogenic bacteria was inadequate at that time, people began to build large-scale sewer systems and install flushing toilets in order to remove human waste from the living environment as quickly as possible.

The direct discharge of domestic wastewater through the sewer systems into rivers caused water pollution in rivers and estuaries. Since water pollution at that time was firstly caused by high oxygen consumption of organic loading from domestic and industrial wastewater, treatment facilities for removing the so called BOD materials were investigated and introduced in practice. After the original activated sludge process was invented and applied in Manchester, England in 1914, the activated sludge processes with a lot of modified processes prevailed all over the world.

In the Japanese experiences, industrial wastewater pollution in the late 1950s became a very significant and serious issue in relation to water pollution control policies and technologies. It was found at this time that trace amounts of toxic heavy metals could be accumulated in living organisms, including fish, shellfish and crops, and that these toxic substances could have a direct impact on human health when ingested through contaminated foods. These toxic substances are never degraded biologically during treatment processes or in the natural environment. It is therefore extremely important to restrict the discharge of these toxic substances in the environment even through sewer systems, and to control them at their sources through the prohibition of their usage or production.

In 1972, serious damage to fisheries was reported as a result of a ‘red tide’ in the Seto Inland Sea in Japan. In almost the same era, the problem of eutrophication in both closed sea areas and lakes and reservoirs became a key area of concern about water pollution in the worldwide. Serious consideration was given to various approaches to the minimization of the amounts of nutrients discharged into natural waters. Among the methods studied were the development of phosphate-free detergents, the introduction of nutrient standards for effluent and environmental standards, and the application of nutrient removal process as an advanced treatment in conventional secondary treatment facilities.

Other topical issues relating to water pollution include the safety of drinking water and the problem of global warming. As discussed above, the safety of drinking water from pathogenic bacteria was the first issue in the history of water pollution. It is both interesting and significant that the safety of drinking water has once again become a topic of concern due to water pollution resulting from advanced industrial activity.

In addition to this new concern about the safety of drinking water, global warming has also emerged as a serious problem for future generations. The relationship between water pollution and global warming is rather complex, since some wastewater treatment processes may produce greenhouse gases, such as methane and nitrous oxide, while complex ecosystems in treatment systems and natural water environments could be affected by global warming.

The historical development of target substances in water pollution problems caused by human civilization and industrialization in Europe and mainly in Japan is summarized in Table 1. It is interesting to note that the construction of modern sewage works in European countries in the early 19th century is listed as the first counter measure for the waterborne disease like cholera as a basic sanitary issue related to water pollution, and the necessity of advanced water treatment technique to remove *Cryptosporidium* oocyst which cause diarrhea and cannot be disinfected by chlorine in water supply system is again listed as one of the latest target of water pollution control.

Era	Target Substances	Countermeasures
1800-	Pathogenic bacteria	Construction of sewer system and disinfection
1900-	Organic materials (BOD material)	Biological treatment and physico-chemical treatment
1950-	Heavy metals and non-biodegradable chemicals	No production and no discharge to environment (treatment at source)
1970-	Nutrient for eutrophication	Nitrogen and phosphorus removal processes
1980-	Trace substances in drinking water (Carcinogen, off-flavors and taste) Micro suspended solids, color and odor	Activated carbon or membrane technologies
1990-	Greenhouse gasses (CH_4, NO_2 and CO_2)	Advanced treatment for water reuse
1995-	*Cryptosporidium* oosyst	Energy saving technologies
1999-	Endocrine disrupting chemicals	Advanced treatment for micro solids separation Surveillance of EDCs in water environment

Table 1: Historical Change of Target Substances in Water Pollution Control

2.2. Collection and Treatment Schemes of Wastewater

The modern sewage system is an underground pipeline system which collects various wastewaters such as domestic wastewater from toilet and other water use as washing, bathing, cooking, and so on, industrial wastewaters, and rain water in some cases. A typical scheme of the sewage system, which is used in Japan these days, is illustrated in Figure 1.

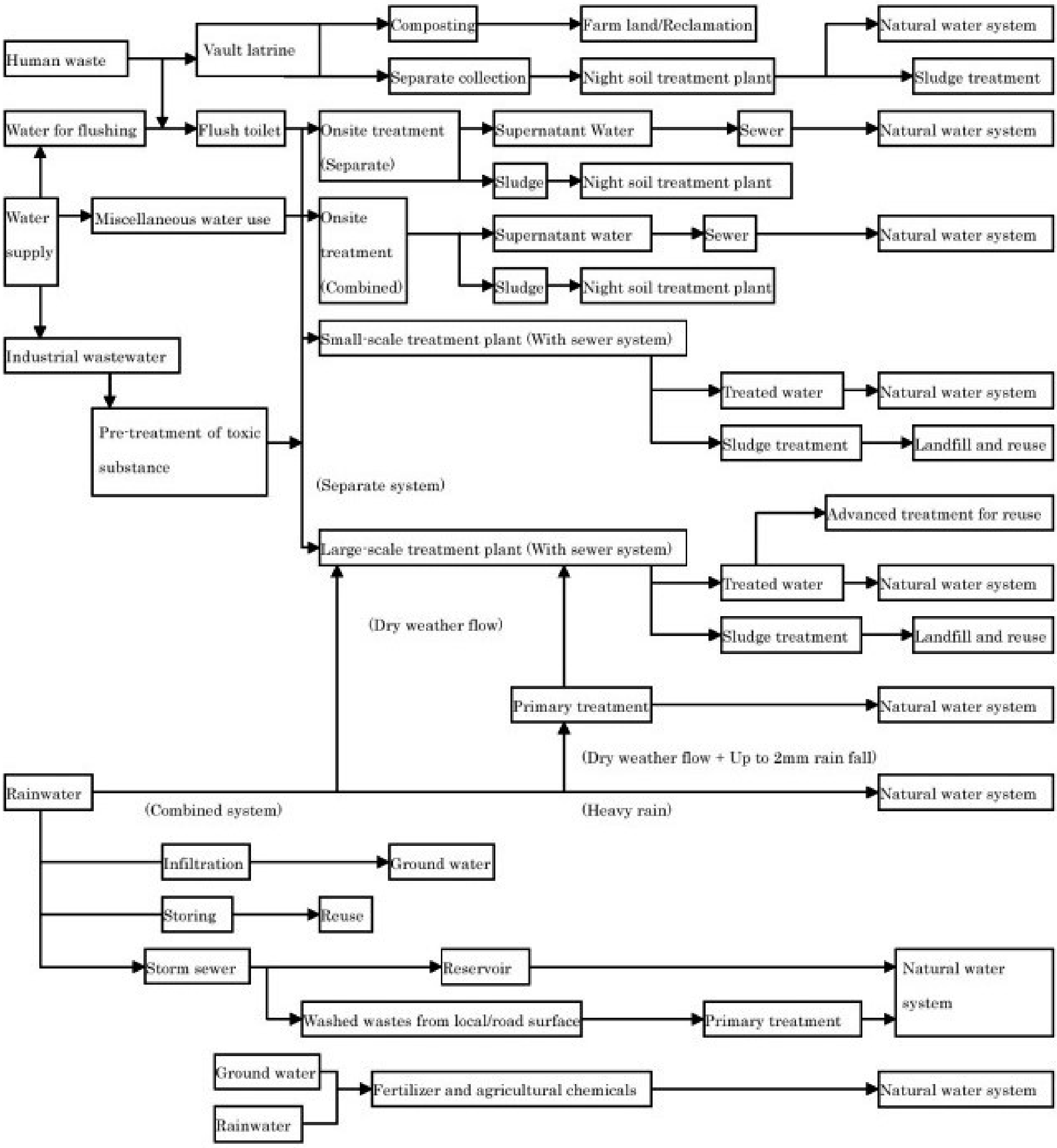

Figure 1: Typical Scheme of Sewage Systems in Japan

In the figure, the first stage starts from the vault latrine and cartage system toilet, in which night soil could be stored for some time and used as source of compost or collected by vacuumed pumping to the night soil treatment plant. At the night soil treatment plant, the collected night soil is treated separately using biological treatments as activated treatment systems and nutrient removal systems. The combined domestic wastewater of night soil with flushing water and gray water from miscellaneous use in the households could be treated at the on-site treatment facilities in one case and, in the other case, the combined domestic wastewater collected by the separate pipeline could be treated in the sewage treatment plant, although the size of the sewage treatment plant might be changing very wide range from 10 to millions m^3 per day.

In some cases, industrial wastewater could be collected in the same pipeline of domestic wastewater and treated same way in the sewage treatment plant, in case that the industrial wastewaters are free from various toxic substances after the specific removal treatment of the toxic substances at the local facilities in the industries. For the collection and discharge of the rainwater or storm water from urbanized environment, sewage systems execute very important function to protect the buildings and properties from flood and preserve the comfortable living condition in the city. The combined sewer systems collect together rainwater and urban wastewater including domestic and industrial wastewater by one pipeline, and the separate systems collect separately rainwater and urban wastewater by two pipelines.

In the recent years, issues related with the water quality control from the combined sewer overflow (CSO) under the rainfall have come to be very hot issues in the water pollution control policy. It is recommended that the storm water from densely inhabited area should be treated simply by screening, sedimentation or disinfection before discharging to the natural receiving water bodies depending on the situation. The term of "wet weather water quality control" gives now very important meaning to basin-wide water quality control planning.

Besides the treatment systems of sewage and sewage sludge, the reuse systems of wastewater and recovery of usable resources from sludge have been taken into consideration to compensate the fresh water supply and recover energy and materials. One of the ideas of reuse systems of wastewater and sludge is illustrated in Figure 2.

In this scheme, the reclaimed water is to be used as toilet flush, landscape irrigation, washing and cooling water. In the anaerobic digestion process, the organic materials in the sludge could be converted into methane gas and used as fuels. Nutrients in the sludge are expected to be used as fertilizers and compost. Inorganic solids in the sludge is melted into slugs and used as construction materials.

2.3. Characterization of Wastewater

2.3.1. Municipal Wastewater

Municipal wastewater generally consists of domestic wastewater, commercial wastewaters and industrial wastewaters. Since their characteristics are remarkably different, water quality and quantity characteristics vary considerably depending on the percentage of wastewater of each origin.

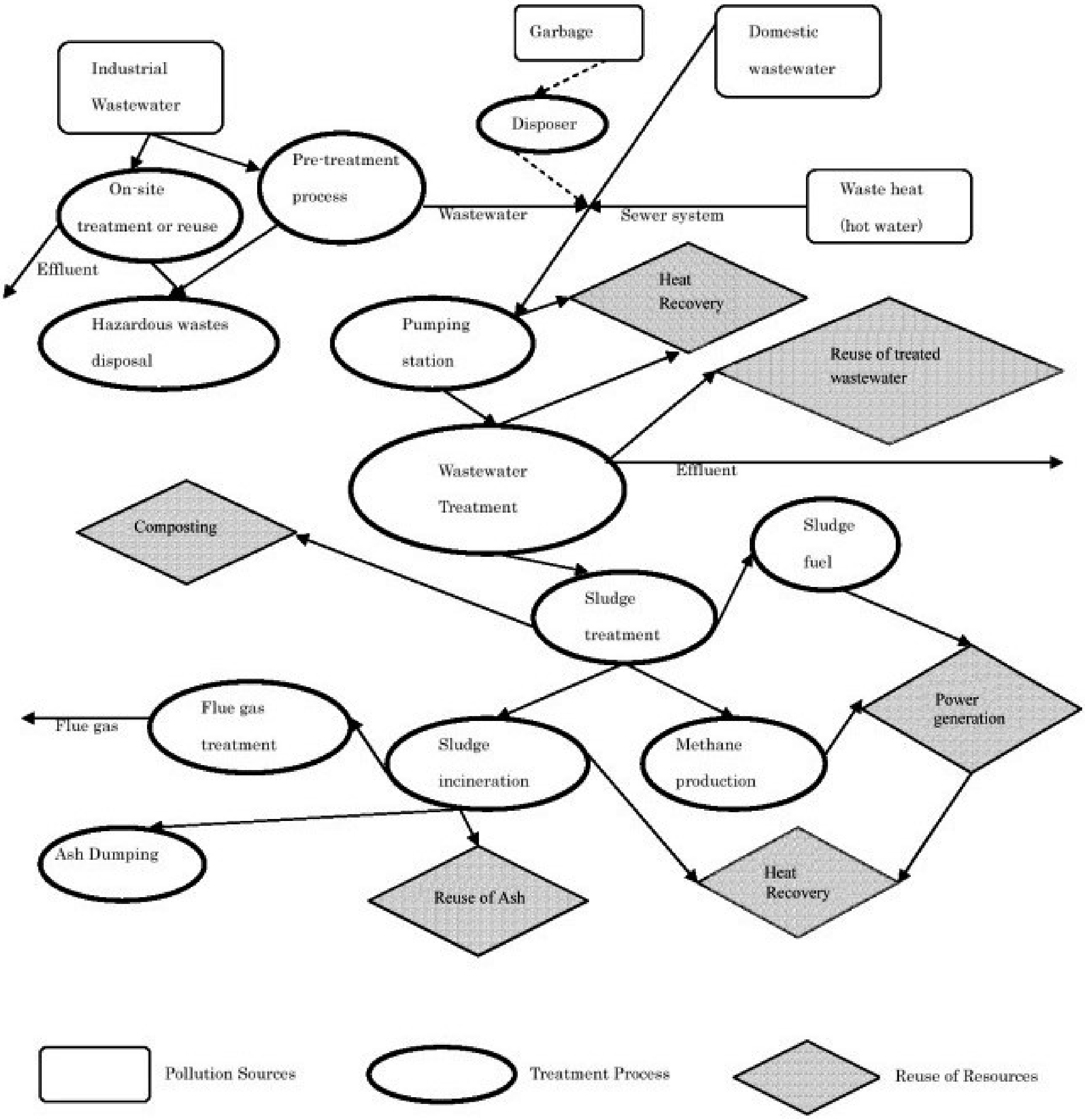

Figure 2: Reuse Systems of Wastewater, Waste Heat, and Sludge

Table 2 shows a typical per capita loading of pollutants in Japan. Although the consumption rate of water is generally high in summer and low in winter, the per capita loading rates do not change so much according to seasons. Therefore, the concentrations of most water quality constituents of domestic wastewater are generally high in winter and low in summer.

Constituent	Loading (g/cap./day)
Biochemical oxygen demand (BOD)	58
Chemical oxygen demand (COD (Mn))	27
Suspended solids (SS)	45
Total nitrogen (TN)	11
Total phosphorus (TP)	1.3

Table 2: Typical per Capita Loading in Japan

Wastewaters from commercial areas show a significant difference depending on the types of commercial activities. Some areas produce wastewaters of high organic loadings with large volume of water, while the others produce low intensity and small volume of wastewaters. Biochemical Oxygen Demand (BOD) of wastewaters from commercial areas is reported to be generally around 100 to 500 mg/l. When industrial wastewaters are involved in the municipal wastewater, the characteristics of industrial wastewaters must be carefully defined since they may seriously affect the removal efficiency of wastewater treatment as well as the quality of sludge.

2.3.2. Industrial Wastewater

Industrial wastewaters considerably differ from industry to industry, from factory to factory. Some industrial wastewaters should not be involved in the municipal wastewater treatment. These include:

(1) Wastewaters harmful to biological processes
(2) Wastewaters harmful to equipment
(3) Wastewaters with potential safety hazards
(4) Wastewaters containing materials not properly treated by the employed processes

These wastewaters include heavy metals, toxic chemicals, extreme pH wastes, highly colored wastes, and large amounts of oil and grease. Factories producing these wastewaters have to install pre-treatment facilities to remove harmful materials to below a required level before discharging the wastewaters into public sewer systems. The wastewaters from food processing factories contain high concentration of organic materials, while wastewaters from metal processing show little organic loadings though they show relatively high inorganic loadings. Wastewaters from so-called high-tech industries producing semiconductors and related products might contain excessive amount of volatile organic compounds (VOCs). Although modern wastewater treatment systems have aeration systems and these VOCs can be stripped off, they should be pre-treated since their effects on biological processes are not well understood and they might be released off to the air during the course of transportation by public sewers.

2.4. Processes for Wastewater Treatment

2.4.1. Screening

Since the municipal wastewater contains variety of visible materials, removal of these materials is at first necessary for the subsequent processes. Screening devices are generally used to remove the visible materials and they can be classified as fine screens or coarse screens. A fine screen can remove significant amount of suspended solids, while a coarse screen is used as a protective device for the other treatment equipment.

Coarse screens are normally used as the first treatment unit for protecting plant equipment against physical damage or degradation of treatment efficiency. Their effectiveness can be measured by examining the maintenance costs and downtime of the other equipment and processes that are protected by the coarse screens. Coarse screens include bar screens, comminutors, and coarser woven-wire media.

Fine screens include fixed or static screens and moving screens. Fixed fine screens with opening of less than 2.5 mm are generally employed. Their removal efficiencies for BOD and Suspended Solids (SS) are commonly in the range of 20 to 35 %. Moving fine screens are continuous cleaned screens with rotating drum. Various materials are used as screens such as stainless steel, nylon, and polyester. The opening of moving screens varies from 0.02 to 3 mm depending on the purposes.

2.4.2. Sedimentation

When wastewaters are in a relatively quiescent condition, solids particles will settle down because of gravity. Gravity settling is a method by which suspended matters are removed. Primary settling tanks are constructed to remove the readily settleable solids prior to subsequent treatment. Final settling tanks are used to remove settleable solids that are produced by biological processes. Settling tanks are also used in the advanced wastewater treatment processes with the dosage of some chemicals. To remove soluble materials such as organics and phosphates by sedimentation, coagulants are used to make flocculants to increase settleability of these materials. Gravity thickening of sewage sludge is performed by gravity settling of sludge.

When wastewater is treated at the primary settling tanks, this level of treatment is generally called primary treatment. In some situations, coagulants are used at the primary settling to enhance the treatment efficiency. This level of treatment is sometimes called as advanced primary treatment. Depending on the concentration as well as property of solids to be removed by settling, these solids materials are classified into three categories.

1. Class I materials
    (1) Solids are discrete particles.
    (2) Settling rate is independent of concentration.
    (3) Settling rate is equal to overflow rate.
2. Class II materials
    (1) Particles will grow during settling.
    (2) Overflow rate and detention time are critical.
    (3) Rate of particle growth is important.
3. Class III materials
    (1) Suspended solids concentration is high.
    (2) Settling rate is a function of the concentration.
    (3) Detention time and solids loading are important.

Primary settling tanks are designed and operated to remove the class I materials. Design and operation of final settling tanks are done aiming at the removal of mixed liquor suspended solids (MLSS) that are belonging to the class II materials. Primary sludge or waste activated sludge (WAS) withdrawn from final settling tanks is usually transported to sludge thickeners where class III materials are settled and thickened. Therefore, settling properties of the class I and class II materials are to be considered in the design and operation of biological wastewater treatment processes and settling properties of the class III materials should be considered in the sludge treatment. Typical concentration levels of solids in wastewater before thickening are shown in Table 3.

Sludge Source	Sludge Concentration (%)
Raw primary, fresh	2.0 – 4.0
Biological, secondary	0.5 – 1.0
Raw primary with waste activated sludge	1.0
Rotating biological contactor (RBC) humus	0.8
Raw primary with RBC humus	1.0
Chemical sludge	
Lime	< 10
Alum and ferric sludge	< 2

Table 3: Solids Concentrations in Wastewater before Thickening

There are basically two types of settling tanks. One is rectangular, and the other is circular. Circular settling tanks are frequently called clarifiers. Geometrical ratios of rectangular tanks commonly are: length vs. width of 3:1 or greater. The width of a tank is usually designed by taking the width of nominal sludge collectors into account. The depth of a tank is 2.5 to 4.0 meters. The floor of a rectangular tank has a slope with the gradient of 1/100 to 2/100 to make the collection of settled sludge easier. Circular tanks have wide range of diameters from 3 to 60 meters. Side water depth is 2 to 3 meters for primary settling, and 3 to 4 meters for secondary settling. Circular tanks usually have a bottom slope of 5/100 to 10/100.

In a rectangular tank, collection of settled sludge is carried out by chain flights or traveling bridges with scraper blades. The chain flights scrapers or scraper blades move the settled sludge to the one end of a tank, usually to the inlet end where sludge hopper is constructed. For a long rectangular tank, a hopper is constructed in the middle of tank. For final settling tanks, the moving bridges are sometimes equipped with suction pipes instead of scraper blades to suck up the settled sludge into a trough along the tank side.

As a modification of a rectangular tank, a square tank is sometimes used. Square tanks are equipped with rotating type scrapers whose mechanisms are similar to circular types. Rotating mechanisms become possible with the installation of exploring rotating arms. Although a square tank makes the best utilization of land, use of exploring rotating arms is not recommended from the standpoints of operation and maintenance.

In a circular tank, collection of settled sludge is done by either scraping type or suction type. While the scraping type is mainly used for primary settling sludge, the suction type is used for activated sludge. When the diameter of a clarifier is greater than 30 meters, a suction type of sludge collector is most commonly used.

For both rectangular tanks and circular tanks, overflow rate is an important operational factor. Overflow rate is the depth of wastewater that is handled by a unit surface area of settling tank in a specific period of time. In the primary settling tank, normal overflow rates of 35 to 70 m^3/m^2/day are used for separate sewer systems, and 25 to 50 m^3/m^2/day for combined sewer systems in Japan. Although detention time for sedimentation is not so important a factor as overflow rate, 1 to 2 hours are usually adopted for primary settling. In the secondary settling tank, overflow rates of 20 to 30 m^3/m^2/day are used.

2.4.3. Activated Sludge Processes

Biological treatment processes by suspended growth type of microorganisms are commonly used for secondary treatment of municipal wastewater. The mass of suspended microorganisms grown under the aerobic condition is called activated sludge. Depending on the reactor types or the modes of operation, a variety of activated sludge treatment processes is developed, such as conventional activated sludge process, extended aeration process, step aeration, oxidation ditch, sequencing batch reactor, contact stabilization process, and pure oxygen aeration process.

(1) Conventional activated sludge process

The conventional activated sludge process is most commonly employed for a wastewater treatment process in developed countries. Figure 3 shows a typical flow diagram of the conventional activated sludge process. A key unit in this process is an aeration tank where organic and inorganic materials in the wastewaters are removed by activated sludge. An aeration tank has normally a depth of 4 to 6 meters, while a deep aeration tank has a depth of about 10 meters.

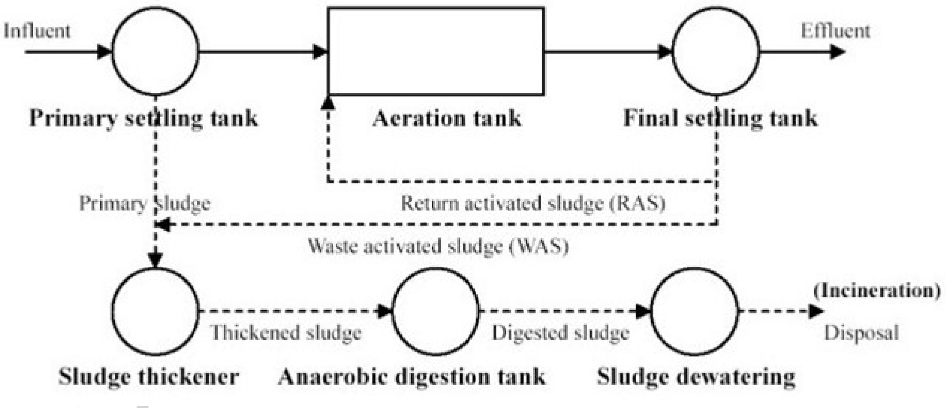

Figure 3: Typical Flow Diagram of Conventional Activated Sludge Process Including Sludge Treatment Processes

Supply of air called aeration is done in an aeration tank through diffusers, though mechanical surface aeration is employed for small plants such as pre-treatment of industrial wastewaters. Aeration has mainly three purposes: first to supply oxygen to the mixture of wastewater and activated sludge called mixed liquor, second to move the mixed liquor fast enough to have good mixing of wastewater and activated sludge, and third to keep activated sludge in suspension. Oxygen transfer efficiency that expresses the percentage of oxygen actually dissolved in the water depends on types of diffusers since the bubble size, which may differ among diffusers, is an important factor for oxygen transfer efficiency. Table 3 shows the oxygen transfer efficiencies and aeration efficiencies based on electric power consumption for diffused aeration systems tested in clean water for some of the typical diffusers employed in Japan.

Aeration Type	Oxygen Transfer Efficiency (%)	Aeration Efficiency (kg/MJ)
Fine bubble aeration		
Normal depth	14 – 16	0.5 – 0.9
Deep depth	15 – 17	0.5 – 0.9
Whole floor	20 – 32	0.8 – 1.3
Course bubble aeration	8 – 13	0.3 – 0.4
Jet aeration	15 – 26	0.4 – 0.6
Submerged turbine aeration	20 – 30	0.4 – 0.6

Table 4: Efficiency of Diffused Aeration in Clean Water Test

Hydraulic retention time (HRT) in the aeration tank is 6 to 8 hours, and solids retention time (SRT) is 3 to 6 days. The concentration of MLSS is 1,500 to 2,000 mg/l and food, and microorganism ratio (FM ratio) is 0.2 to 0.4 (kg BOD/kg SS/day). Although the ratio of returned activated sludge (RAS) to the influent flow is varied with the operational MLSS concentration, ratio of around 0.5 is usually adopted for MLSS in the range of 1,500 to 2,000 mg/l. As a reactor type, complete mixing is only employed for small plants and plug flow type is normally applied. Under these normal operational conditions, removal efficiencies of the conventional activated sludge process for BOD and SS are expected more than 90 %. The process has, however, some deficiencies in that (1) the oxygen requirements at the head of aeration tank often exceed the aeration rate, and (2) the aeration tanks are not good approximation of stirred tanks or plug-flow processes, as there is a considerable amount of back mixing in long narrow tanks. To improve these deficiencies, a number of modifications of the conventional process were developed during the 1950s such as step aeration or tapered aeration.

In step aeration, influent of wastewater to an aeration tank is dividedly fed into several lower stream points of an aeration tank as well as the head of a tank. Such step feeding of wastewater into an aeration tank makes the oxygen consumption rate in an aeration tank relatively uniform and high oxygen consumption rate at the head of an aeration tank experienced in the conventional process can be avoided.

Since the oxygen consumption rate of activated sludge gradually decreases from the upper end to the lower end of an aeration tank, the rate of aeration can be reasonably varied according to the direction of flow in an aeration tank. This process is called tapered aeration. Supply of oxygen is matched to the oxygen demand of the activated sludge and the deficiency problems can be solved by the tapered aeration.

(2) Extended aeration process

Since some of the other modification processes can be operated as extended aeration with relatively long SRT and low FM ratio, typical modification processes are explained. In the extended aeration process, production of the excess sludge can be reduced compared to the conventional process and nitrification proceeds relatively easily. Since ammonia is toxic to fish and other aquatic organisms, nitrification is favorable because the ammonia concentration of the effluent becomes relatively low. Primary settling process is usually neglected. HRT in the aeration tank of 16 to 24 hours and SRT of 13 to 50 days are generally applied. To keep the relatively long SRT, high concentration of MLSS in the range of 3,000 to 4,000 mg/l is maintained under the normal conditions. FM ratio is as low as 0.05 to 0.10 (kg BOD/kg SS/day).

A rectangular aeration tank, an oxidation ditch (OD) type reactor, or a sequencing batch reactor (SBR) can carry out the extended aeration process. OD and SBR will be described as the processes of advanced wastewater treatment.

Recent advancement of material industries makes it possible to use membranes with very fine pore size. Membranes with nominal pore sizes of 0.1 to 0.5 microns are used as filters for the effluent to pass and for the activated sludge to remain in the reactor. Membrane separation or microfiltration (MF) activated sludge process is relatively a new process. There are several types of membranes such as plane membranes, string membranes, and tube membranes. MF activated sludge process is compacted in scale and produces high quality effluent. Since the activated sludge is retained in the reactor, there is no need of RAS and no need of either primary settling tanks or final settling tanks. MLSS is around 12,000 mg/l and SRT is 20 to 40 days, though HRT is usually around 6 hours. Removal efficiency of BOD and SS is as high as 98 % and almost 100%, respectively. Since the pore sizes are very fine, continuous cleaning of the surface of membranes is necessary to avoid clogging problems. For the cleaning purpose, gas to flow ratio (GQ ratio) of 40 to 50 is used in the membrane process, while GQ ratio of conventional activated sludge process is around 5. Therefore, in spite of its advantages of high quality effluent and less land requirements, high consumption of energy by membrane process discourages its adoption where price of electricity is high.

2.4.4. Biofilm Processes

Biofilm attached to solid surfaces used to be widely applied to remove soluble or colloidal organics from wastewaters. Biofilm reactors include such processes as (1) trickling filters, (2) rotating biological contactors (RBC), (3) anaerobic filters, (4) submerged filters, (5) biological fluidized beds, (6) activated biofilters, and so on. The bulk substrate removal is thought to comprise three main processes as (a) substrate transport from the bulk to the biofilm, (b) molecular diffusion of the substrate within the biofilm, (c) metabolic reactions within the biofilm. Therefore, in these processes, the removal efficiency of organics is considered limited by the mass transfer resistance in liquid and biofilm phases.

Biofilm plants are employed mainly for industrial wastewater treatment and advanced wastewater treatment, whereas the rate of biofilm plants used for secondary treatment is less than 5 % of the whole municipal wastewater treatment plants in Japan.

In the following, (1) trickling filters and (2) RBC, which are used as biofilm processes for secondary treatment in Japan, will be briefly described.

(1) Trickling filter

Trickling filters historically have been popular for use in small plants, because of their ability to recover from shock loads and to perform well with a minimum of skilled technical supervision, and because of their economy in capital and operating costs.

There are many types of media such as crushed trap rocks, granite, limestone, hard coals, cokes, cinders, blast-furnace slag, wood, ceramic materials, and plastics. Trickling filters also have been historically classified into high rate filters or standard rate filters, depending on the organic and hydraulic loadings applied to the filters.

(2) Rotating biological contactors (RBC)

In RBC, about 40 percents of the total surface area of disks are always submerged. During the rotation of disks, the fixed biofilm absorbs organics and oxygen. Although RBC is an efficient process removing organics, it would have a deficiency that the biomass detached from disks sometimes changes into fine dispersed flocks in the reactor and the color of effluent becomes white. Thus, a new system, in which the detached biofilm is drawn directly from the RBC reactor, has been under study.

2.4.5. Stabilization Ponds and Aerated Lagoons

Treatment of wastewaters can be simply done by introducing the wastewaters into ponds. The pond processes are classified as follows:

(a) Aerobic ponds: shallow ponds, less than 1 meter in depth, where dissolved oxygen is maintained throughout the entire depth mainly by the photosynthetic reactions.

(b) Facultative ponds: ponds with the depth of 1.0 to 2.5 meters, having an anaerobic lower zone, a facultative middle zone, and an aerobic upper zone maintained by photosynthesis and surface reaeration.

(c) Anaerobic ponds: deep ponds receiving high organic loadings such that anaerobic conditions prevail throughout entire pond depth.

(d) Maturation or tertiary ponds: ponds used for polishing effluents from other biological processes. Dissolved oxygen is furnished through photosynthesis and surface reaeration. This type of pond is also known as a polishing pond.

(e) Aerated lagoons: ponds oxygenated through the action of surface or diffused air aeration.

The processes (a), (b) and (e) are commonly used for secondary treatment of wastewater. Since sunlight penetrates into the bottom of aerobic ponds, the metabolic reactions of bacteria and algae complement each other. Since algae produce the oxygen in the photosynthetic reaction, aerobic bacteria can degrade organic compounds using the oxygen supplied by algae. In facultative ponds, not only aerobic zone but also anaerobic zone and facultative zone exist. Therefore, many kinds of biological reaction occur in the pond system.

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Biographical Sketches

Tomonori Matsuo graduated from the Department of Civil Engineering at the University of Tokyo in 1963. In 1966 he started his research carrier at the Department of Urban Engineering of the same university and he was promoted to Professor of Environmental Engineering at the Department in 1982. He retired from the University of Tokyo in March 2000 and moved to the Department of Regional Development Studies, Toyo University in April 2001. He is currently in charge of Dean, Graduate School of Regional Development Studies, and Director, Center for Sustainable Development Studies, Toyo University.

Eiichi Nakamura was Director of Water Quality Control Dept., National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Tsukuba, Japan and is presently Vice President of Showa Information Process Co., Ltd. since 2002. He has B.S. in Sanitary Engineering from University of Tokyo, M.S. in Environmental Engineering from University of Illinois at U-C, and Dr. Eng. from University of Tokyo. He used to be involved in stormwater pollution control in sewered areas, such as caused by combined sewer overflows, storm waters and sanitary sewer overflows. He had also worked in the field of eutrophication control in rivers and lakes. He is a member of IWA, JSWE, WEF, JSWA, JSCE, JSWRE and Tsukuba Science Academy.

Masahiro Osako is Senior Researcher of Hazardous Waste Management Section in Research Center for Material Cycles and Waste Management of National Institute for Environmental Studies since 2000. He has Dr. Eng. in Environmental Sanitary Engineering from Kyoto University. He has responsibilities to conduct several research projects associated with ash management, landfill management, POPs control measures, prevention for illegal dumping and life-cycle assessment. He had also worked in the field of odor evaluation and control engineering. He is a visiting associate professor of Tokyo Institute of Technology.