ALTERNATIVE SEWAGE DISPOSAL SYSTEMS

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Summary

The main factors to be considered when selecting a wastewater treatment process are (1) Size of the community, (2) Operators' technical level, (3) Cost recovery capability, (4) Available land, and (5) Required effluent quality. Technologies mainly discussed here are (i) Stabilization ponds, (ii) Oxidation ditches, (iii) Trickling filters, and (iv) Activated sludge process. Stabilization ponds are suitable if the community served is small; and/or experienced operators are unavailable; and/or large land area is available. The activated sludge method is to be employed in the opposite cases. As to the quality of effluent water, an advanced treatment method may have to be designed in place of the conventional process. Stabilization ponds are more suitable in the tropics than regions situated at higher latitudes. As the design method advances, modern oxidation ditches can remove not only BOD and SS but also substances such as nitrogen, so they are now used in medium-sized communities as well as small ones. The treatment by trickling filters is achieved by the biological growth in a non-moving medium in the filter, and used in combination with primary and secondary settling basins. Although the method has advantages of simple operation and ability to work in relatively cold climate, it is becoming unpopular due to the large land required and the inferior clarity of its effluent. In the activated sludge process, organic matter in the raw wastewater is removed by metabolic assimilation of the microorganisms in the MLSS in the aeration tank. To achieve high performance, the activated sludge is recirculated from the secondary sedimentation basin to the aeration tank, while the excessive fraction is discharged for disposal. The disposal of sludge from any treatment process should be carried out by combination of such processes as thickening, dewatering, aerobic and/or anaerobic digestion, and incineration.

1. General

There are a wide range of alternative methods for the disposal of sewage and wastewater. Until modern times, and even today in some rural communities, sewage is collected from toilets and disposed by dumping into a wasteland, or water body. In some cases, it is stored for a period of time so it can be applied to farmlands as fertilizer. In industrialized countries, sewage (and wastewater) is collected by means of sewers and treated by sophisticated treatment processes prior to discharge to the environment. As industrialization progressed, the application of sewage to farmlands was gradually replaced by chemical fertilizer. Thus, the need has arisen for sewage to be treated even in small or rural communities. Historically, various sewage treatment methods have been invented and practiced in succession.

2. Selection of sewage treatment method

The following are the factors and available sewage treatment technologies to be considered for their selection in the light of the respective factors (except for household-oriented technologies).

2.1. Size of the community (service area)

(1) Small: (a) Stabilization ponds (lagoons)
(b) Aerated lagoons
(c) Oxidation ditches

(2) Large: (c) Oxidation ditches
(d) Trickling filters
(e) Conventional treatment process (activated sludge process)

2.2. Technical level of plant operators

(1) Low: (a) Stabilization ponds (Lagoons)
(b) Aerated lagoons
(c) Oxidation ditches
(2) High: (d) Trickling filters
(e) Conventional treatment process

2.3. Cost recovery capability

(1) Low: (a) Stabilization ponds (Lagoons)
(b) Aerated lagoons
(c) Oxidation ditches
(2) High: (c) Oxidation ditches
(d) Trickling filters
(e) Conventional treatment process

2.4. Available land space

(1) Small: (c) Oxidation ditches
(e) Conventional treatment process
(2) Large: (a) Stabilization ponds (Lagoons)
(b) Aerated lagoons
(c) Oxidation ditches
(d) Trickling filters

Small communities generally have the advantage of availability of land space, but are characterized by inexperienced operators and low cost recovery capability.

2.5. Required effluent water quality

Where the requirements of effluent water quality are stringent, the level of water treatment should unavoidably be high, whereas lower level of water treatment may be allowed where the conditions are less stringent, e.g. (1) the treatment facility is too small with respect to the size of the receiving water body; (2) the standards of effluent water are not high; or (3) the treated water is not discharged to the natural water bodies, but brought to farmlands for irrigation. The selection of wastewater treatment processes in accordance with effluent water quality conditions will be as follows:

(1) Stringent conditions:	(e) Conventional treatment process
	(f) Advanced treatment process
(2) Less stringent conditions:	(a) Stabilization ponds (Lagoons)
	(b) Aerated lagoons
	(c) Oxidation ditches
	(d) Trickling filters

The examples of the advanced treatment processes are as follows:

- Circulated nitrification-denitrification process (for nitrogen removal)
- Carrier-aided denitrification process (do)
- Nitrification-endogenous process (do)
- Coagulant-aided circulated nitrification-denitrification process (for the removal of nitrogen and phosphorus)
- Coagulant-and-carrier-aided denitrification process (do)
- Anaerobic-anoxic-aerobic process (A2O process) (do)
- Coagulant-aided nitrification-endogenous process (do)

The following processes may be added to the above biological processes for the removal of some suspended solids and other dissolved matter such as odor, color, MBAS, TOC, chlorides, etc.

- Sand filtration + granular activated carbon adsorption (with or without ozonation)
- Sand filtration + membrane filtration

For membrane filtration, the micro-filtration (MF), ultra-filtration (UF), nano-filtration (NF) and reverse osmosis (RO) are available in the order of their pore size (large to small). They are, however, seldom used in wastewater treatment due to their high cost.

3. Design criteria for the individual treatment methods

3.1. Stabilization ponds

Although as simple as septic tanks, stabilization ponds are often as effective as a complete conventional sewage treatment plant. The stabilization pond is more suitable in the tropics, where algae grow rapidly, than regions at high latitudes. Oxygen needed for the metabolism of bacteria in the pond, namely, treatment of sewage, is transferred from the atmosphere into water as well as the production by algae. However, the amount of oxygen produced by algae is far more than that transferred at the air-water interface. The following are basic considerations for the design of stabilization ponds.

3.1.1 Flow diagram

A diagram of the standard layout of a plant using the stabilization pond method is shown in Figure 1.

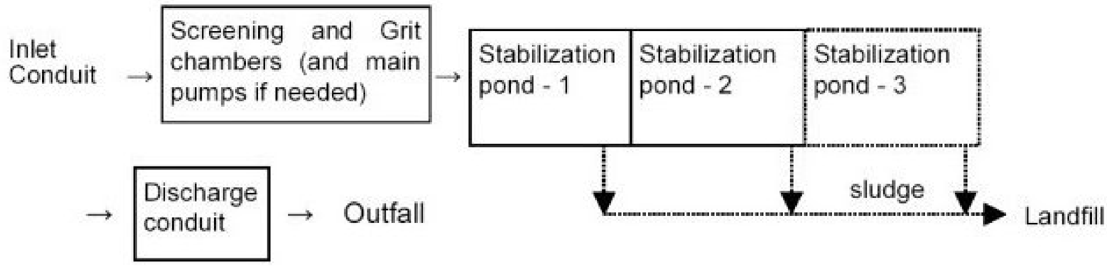

Figure 1. Flow diagram of stabilization ditch process

3.1.2 Screening and grit removal

Floating suspended solids in sewage may need to be removed before entering the stabilization ponds. Floating matter can conveniently be removed by providing coarse bar screens with 50 to 75 mm openings in the inlet chamber. Generally grit removal is not performed unless the quantity of grit is excessive mainly to save construction cost.

3.1.3 Depth of the pond

The depth of stabilization ponds should not be less than 0.9 m. Conversely, depth greater than 1.5 m promotes anaerobic conditions in the pond. Freeboard above the maximum water level in the pond is usually 0.6 to 0.9 m.

3.1.4 Multiple units

For large installations, it is advisable to have two or more small ponds in parallel rather than one big one to provide more facilities for repairs, maintenance and operational flexibility. Ponds can be arranged either in series or parallel. Parallel ponds give equal load distribution, whereas serial ponds have the advantage of producing superior effluents. Serial ponds imply high BOD loading in the primary ponds and relatively low BOD loading in the secondary ponds. Anaerobic conditions may prevail accompanied by some odor in the primary pond while aerobic conditions will occur in the secondary ponds.

3.1.5 Area of the pond required

Owing to higher water temperatures and stronger solar radiation, higher BOD loading can be made in the low latitude regions rather than in high latitudes. As experienced in India, 300 kg-BOD ha^{-1} day^{-1} at a latitude of 12 degrees, 250 kg-BOD ha^{-1} day^{-1} at 16 degrees, and 200 kg-BOD ha^{-1} day^{-1} at 20 degrees can be applied. At lower latitudes a removal rate of 80 to 90% can easily be attained with the BOD loading rate of 300 to 400 kg ha^{-1} day^{-1}. In accordance with experience in India, the total retention time of the pond, depending on the latitude and other conditions, varies widely from 2 to 25 days, averaging about 9 days.

3.2. Oxidation ditches

Oxidation ditches are suitable for small-scale sewer systems, and of late employed in the largest number of cases. The most popular range of treatment flow is between 700 and 2500 m^3 day^{-1}. In this section, the type of oxidation ditches, which employs the vertical axis rotating paddles (aerators), is presented.

3.2.1 Flow diagram

A diagram of the standard layout of a plant using the oxidation ditch method is shown in Figure 2.

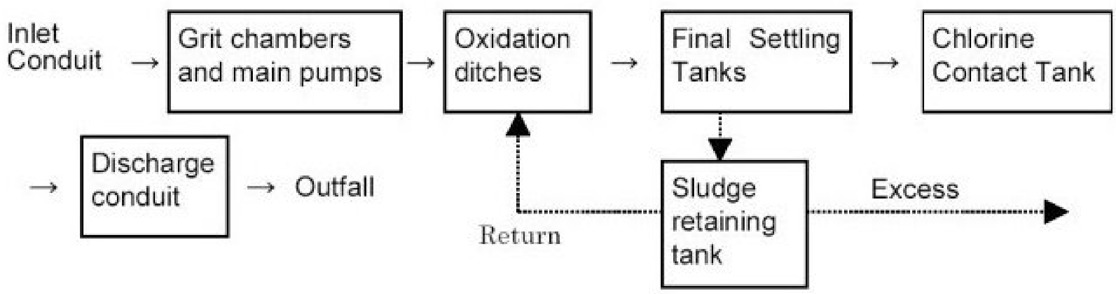

Figure 2. Flow diagram of oxidation ditch process

Oxidation ditches should be designed in a horseshoe-shape in order to take advantage of the vertical aerators (Figure 3). If a horseshoe shape is not feasible, an oval design can be adopted.

3.2.2 Fundamentals of design

Oxidation ditches must be designed so as to make stepwise expansion easy.

The principal quality standards of influent sewage must not be too distant from the following:

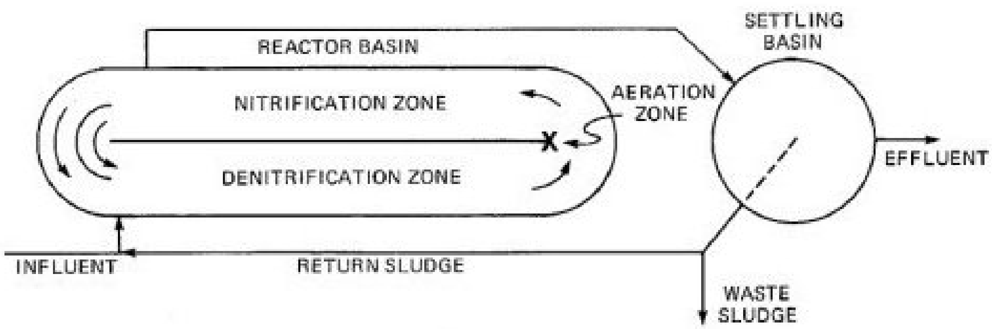

Figure 3. Plan of an oxidation ditch (arranged for nitrification-denitrification)

BOD: 200 mg L^{-1}
SS: 200 mg L^{-1}
Kj-N: 35 mg L^{-1}

Otherwise, the volume of the oxidation ditch as well as the size or capacity of the aerators must be adjusted accordingly.

Design conditions:

(1) Design flow:

Daily average flow = 0.75 ×daily maximum flow (1)

Hourly maximum flow = 2.0 × daily maximum flow (2)

(2) Design water quality

Item	Design Water Quality (mg/L)		Removal rate (%)
	Influent sewage	Treated water	
BOD	200	less than 20	90
SS	200	less than 30	85

Source: Proposed Design Criteria for Oxidation Ditches, Association for Extension of Sewerage Works, Japan (1987)

Table 1. Design water qualities

(3) Design factors of the oxidation ditch

The design factors of the oxidation ditch are generally set as in Table 2.

Item	Design Factor	Standard design
HRT (hr)	24-48	24
MLSS concentration (mg L^{-1})	3000 - 4000	4000
BOD-SS loading (kg-BOD/kg-SS day^{-1})	0.03 - 0.05	0.05
Sludge return ratio (%)	100 - 200	100 - 200
Oxygen requirement (kg-O_2 kg^{-1}-influent BOD)	1.4 - 2.2	1.6

Source: Proposed design criteria for oxidation ditches. Association for Extension of Sewerage Works, Japan (1987)

Table 2. Design factors of the oxidation ditch

(4) Actual Oxygen Requirements (AOR)

$$AOR = O_{D1} + O_{D2} + O_{D3} + O_{D4} \quad (3)$$

where,

O_{D1}: Amount of oxygen required, for oxidizing BOD (kg-O_2 day^{-1})
O_{D2}: Amount of oxygen required for endogenous respiration (kg-O_2 day^{-1})
O_{D3}: Amount of oxygen required for nitrification (kg-O_2 day^{-1})
O_{D4}: Amount of oxygen leaving the reactor basin together with effluent water (kg-O_2 day^{-1})

Assuming influent BOD at 200 mg L^{-1}, influent Kjeldahl nitrogen (Kj-N) at 35 mg L^{-1} and MLSS at 4000 mg L^{-1}, AOR will be computed as follows:

$$AOR = 1.38\ [\text{kg-}O_2\ \text{kg}^{-1}\text{-BOD}] \times \text{BOD to be removed}\ [\text{kg-BOD day}^{-1}] \quad (4)$$

(5) Standard Oxygen Requirements (SOR)

SOR denotes the amount of oxygen required on the standard conditions: fresh water, temperature at 20 ^oC, at atmospheric pressure (101.325 kPa). SOR is calculated as follows:

$$SOR = 1.6\ [\text{kg-}O_2\ \text{kg}^{-1}\text{-BOD}] \times \text{BOD to be removed}\ [\text{kg-BOD day}^{-1}] \quad (5)$$

(6) Number of Aerators and Operating Time

Aerators of a design, which assures efficient oxygen transfer and mixing, should be selected, and two units should be installed per tank.

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Biographical Sketches

Katsuyoshi Tomono is Senior Engineering Adviser of Environmental Planning Institute, Tokyo Engineering Consultants, Co., Ltd., where he has worked since 1999. He graduated from Hokkaido University and received the degree of Bachelor of Engineering in Sanitary Engineering in 1961. After graduation, he worked for Nihon Suido Consultants, Co., Ltd. from 1961 to 1980. He served as Manager of Design Division with responsibilities for planning, design and construction supervision of water supply and sewer system projects in Japan and abroad, and studies on water treatment engineering and economic evaluation on projects. He then spent seven years as Project Engineer at Infrastructure Department, Asian Development Bank until 1987. He was responsible for appraisal and evaluation of bank-financed loan projects in the water supply, sewerage and sanitation sectors. From 1987 to 1999, he worked for the Japan Water Works Association as Senior Researcher for several fields, including development studies on advanced water treatment, high-pressure water service, risk management, etc.

He has authored or co-authored many research articles for the Japan Water Works Association and American Water Works Association over more than 20 years. His subjects of study includes the art of water treatment in Japan, the costs and benefits of risk management in water supply, and the economies of scale in water supply.

Yasumoto Magara is Professor of Engineering at Hokkaido University, where he has been on faculty since 1997. He was admitted to Hokkaido University in 1960 and received the degree of Bachelor of Engineering in Sanitary Engineering in 1964 and Master of Engineering in 1966. After working for the same university for 4 years, he moved to National Institute of Public Health in 1970. He served as the Director of the Institute since 1984 for Department of Sanitary Engineering, then Department of Water Supply Engineering. He also obtained a Ph.D. in Engineering from Hokkaido University in 1979 and was conferred an Honorary Doctoral Degree in Engineering from Chiangmai University in 1994. Since 1964, his research subjects have been in environmental engineering and have included advanced water purification for drinking water, control of hazardous chemicals in drinking water, planning and treatment of domestic waste including human excreta, management of ambient water quality, and mechanisms of biological wastewater treatment system performance. He has also been a member of governmental deliberation councils for several ministries and agencies including Ministry of Health and Welfare, Ministry of Education, Environmental Agency, and National Land Agency. He meanwhile performs the international activities with JICA (Japan International Cooperation Agency) and World Health Organization. As for academic fields, he plays a pivotal role in many associations and societies, and has been Chairman of Japan Society on Water Environment.

Professor Magara has written and edited books on analysis and assessment of drinking water. He has been the author or co-author of more than 100 research articles.