

WATER QUALITY ENGINEERING FOR PRACTICING ENGINEERS

W. Wesley Eckenfelder, Jr.

Department of Environment and
Water Resources Engineering
Vanderbilt University



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6

Wastewater-Treatment Processes

There are a large number of wastewater-treatment processes in use whose application is related both to the characteristics of the waste and the degree of treatment required. The various processes as a treatment sequence and substitution diagram are shown in Fig. 6.1. Pretreatment or primary treatment is used for the removal of floating and suspended solids and oils, neutralization and equalization, and to prepare the wastewater for subsequent treatment or discharge to a receiving water. General considerations in pretreatment or primary treatment for secondary biological treatment are summarized in Table 6.1 (more specific details are given on p. 189). The processes gen-

Table 6.1. Pretreatment or Primary Treatment Requirements for Biological Processes

Characteristics	Treatment
Suspended solids	Lagooning, sedimentation, and flotation
Oil or grease	Skimming tank or separator
Heavy metals	Precipitation or ion exchange
Alkalinity	Neutralization for excessive alkalinity
Acidity	Neutralization
Sulfides	Precipitation or stripping
BOD loading	Equalization

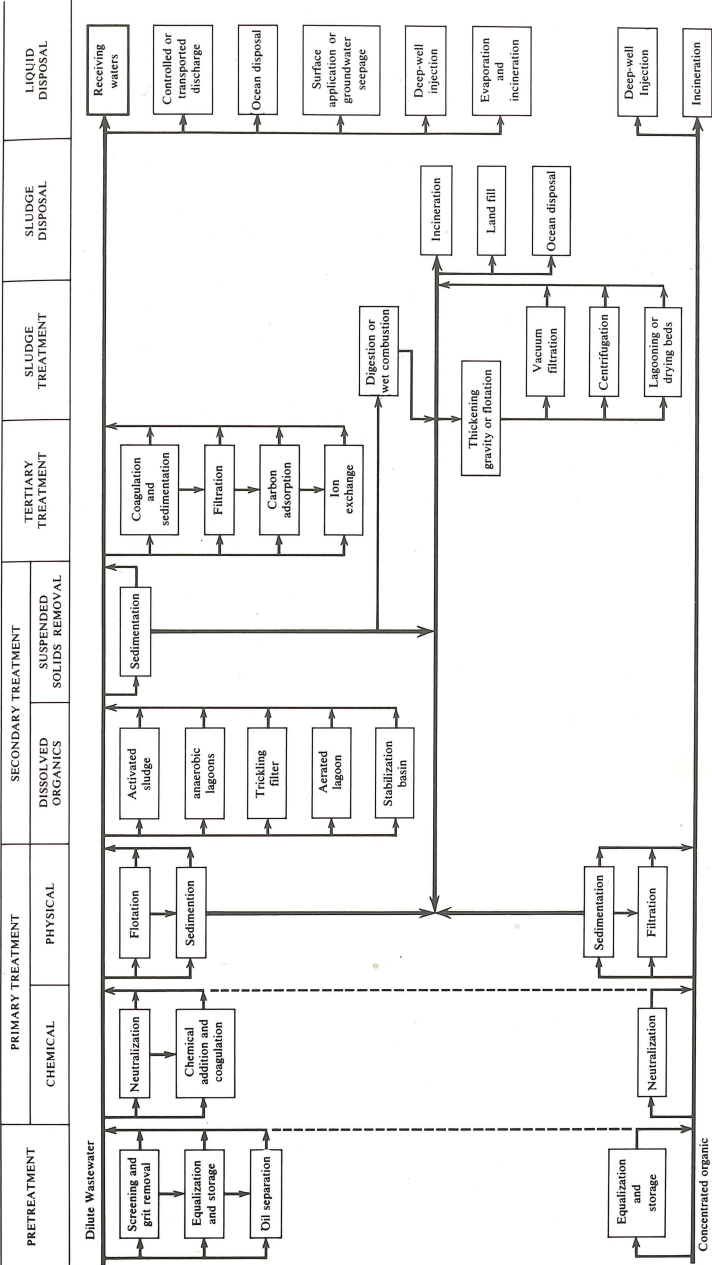


Figure 6.1 Wastewater-treatment sequence: processes substitution diagram.

erally applicable to the removal of specific pollutants are shown in Table 6.2. The characteristics of the effluent from

Table 6.2. Processes Applicable to Wastewater Treatment

Pollutant	Processes
Biodegradable organics (BOD)	Aerobic biological (activated sludge), aerated lagoons, trickling filters, stabilization basins, anaerobic biological (lagoons, anaerobic contact), deep-well disposal
Suspended solids (SS)	Sedimentation, flotation, screening
Refractory organics (COD, TOC)	Carbon adsorption, deep-well disposal
Nitrogen	Maturation ponds, ammonia stripping, nitrification and denitrification, ion exchange
Phosphorus	Lime precipitation; Al or Fe precipitation, biological coprecipitation, ion exchange
Heavy metals	Ion exchange, chemical precipitation
Dissolved inorganic solids	Ion exchange, reverse osmosis, electrodialysis

these processes under optimum operation are summarized in Table 6.3.

The selection of a wastewater-treatment process or a combination of processes will depend upon:

1. The characteristics of the wastewater.
2. The required effluent quality.
3. The costs and availability of land.
4. The future upgrading of water-quality standards.

Each of the processes and the applicable design criteria are discussed in detail in subsequent sections of this book.

7

Pretreatment and Primary Treatment

Pretreatment and primary treatment are employed primarily for the removal of floating materials and suspended solids and for conditioning the wastewater for discharge to waters of low classification or secondary treatment through neutralization and/or equalization. The various processes used in pretreatment and primary treatment are shown on page 109. The primary-treatment requirements for secondary treatment are summarized on page 189.

SCREENING

Screening is employed for the removal of large solids prior to other treatment processes. In municipal sewage treatment, screens are usually provided at the head end of the plant for the removal of coarse materials. The screens consist of coarse bars or racks with $1\frac{1}{2}$ - to $2\frac{1}{2}$ -in. (3.8 to 6.4-cm) openings and may be either mechanically or manually cleaned, as shown in Fig. 7.1. The quantity of screenings which might be expected from municipal sewage are discussed on page 244.

Screens for industrial waste treatment are usually of the rotary, vibrating, or eccentric type and are widely used in the canning, brewing, and pulp and paper industries.

SEDIMENTATION

Sedimentation is employed for the removal of suspended solids from wastewaters. The process can be considered in

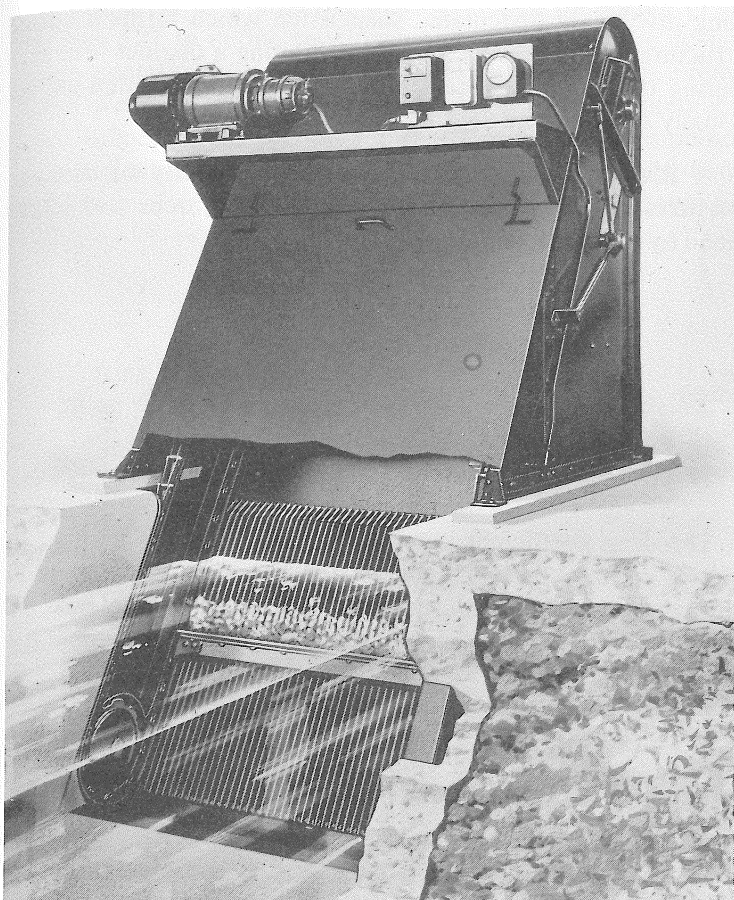


Figure 7.1 Mechanical sewage screen. (Courtesy of Rex Chainbelt, Inc.)

three basic classifications, depending on the nature of the solids present in the suspension: discrete, flocculent, and zone settling. In discrete settling, the particle maintains its individuality and does not change in size, shape, or density during the settling process. Discrete settling is observed with suspensions of grit (grit chambers), fly ash, and coal. Flocculent settling occurs when the particles agglomerate during the settling period, resulting in a change in size and settling rate. Examples include domestic sewage and pulp and paper wastes. Zone set-

The coefficient f is a proportionality factor containing the heat-transfer coefficients, the surface-area increase from the aeration equipment, and wind and humidity effects.

In equation (18c), when Q is in mgd and A in square feet, f has an approximate value of 12×10^{-6} for the central portion of the United States [19]. In computing the estimated lagoon temperature, local weather bureau records are employed to define T_a .

AEROBIC BIOLOGICAL TREATMENT DESIGN

Effective biological treatment requires pretreatment for removal of contaminants which would cause operating problems or upset in the biological process. These can be summarized:

Pretreatment or Primary Treatment

1. If suspended solids are present in excess of approximately 125 mg/l, solids separation by lagooning, sedimentation, or flotation should be considered. For estimating purposes only, a sedimentation tank would have an overflow rate of about 1000 gpd/ft² (4080 m³/day/m²).
2. If oil, grease, or flotables exceed 50 mg/l, a skimming tank or separator should be provided.
3. Heavy metals (Cu, Zn, Ni, and so on) should be removed prior to biological treatment.
4. a. If the pH exceeds pH 9.0, neutralization should be provided if the ratio of caustic alkalinity (expressed as CaCO₃) to COD removed exceeds 0.7 lb of CaCO₃/lb of COD or 0.56 lb of CaCO₃/lb of BOD₅ removed. Neutralization need only reduce the alkalinity to the aforementioned levels.
b. In some cases where a wide variation in alkalinity is encountered during the day or plant operating schedule, the aforementioned levels can be achieved by providing an equalization tank or pond.
5. If the waste contains organic acids, biooxidation will convert these acids to CO₂ and bicarbonate salts, provided the process design reduces these to < 25 mg/l as BOD₅.
6. When mineral acids are present, neutralization or equalization should be provided if the pH is less than 4.5.

7. Sulfides should be prestripped or otherwise removed if their concentration exceeds 50 mg/l.

8. If the influent BOD loading in lb/day, based on 4-hr composites, exceeds a 3:1 ratio, an equalization tank should be considered to bring the variation within this range.

After selection of the possible consideration, the preliminary design calculations should be developed as follows. This procedure presumes that no pilot-plant or laboratory-scale treatment study data are available. If such data are available, the appropriate coefficients and factors developed from the laboratory study should be used.

General

1. Select the appropriate k , a , a' , b , and b' . It should be recognized that at this time there is limited data on the treatment of many industrial wastes, so some of the coefficients are necessarily estimations. As more data are accumulated, these coefficients will be refined.

2. Each of the processes are designed using the equations shown in Table 9.4. It is important to remember that the coefficients generally apply to all systems, and the principle differences between systems are the changes in concentration of biological solids and retention time with the exception of the aerated lagoon, which has a feedback of BOD from the anaerobic sublayer.

Aerobic Lagoons

1. The required retention period for a specified effluent soluble BOD is estimated by combining equations (12a) and (16).

$$t, \text{ days} = \frac{1}{24 aks_e - b}$$

2. The equilibrium volatile solids in the lagoon is computed from equation (16):

$$X_v = \frac{S_0 + as_r}{1 + bt}$$

and the total suspended solids is

$$X_a = \frac{X_v}{\text{volatile fraction}}$$

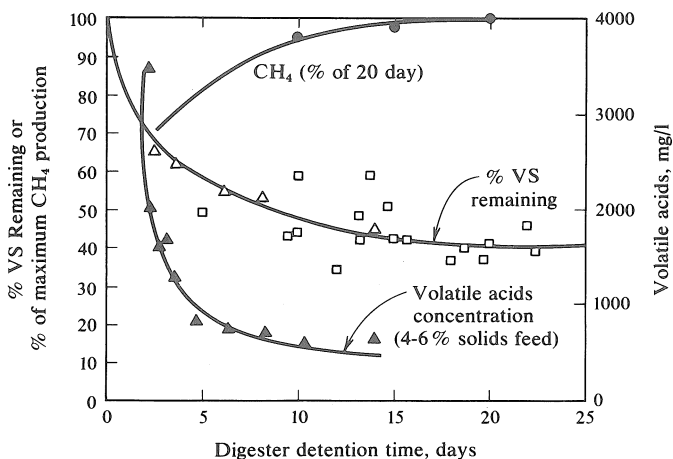


Figure 9.27 High-rate anaerobic digester performance. Data: triangles, Torpey [24]; squares, Estrada [30]; Sawyer [31].

PROCEDURE FOR THE DESIGN OF ANAEROBIC PROCESSES

Data to Be Collected

1. Waste flow, (Mgd) (m^3/day), and fluctuations
2. Waste characteristics
 - a. Suspended solids and volatile suspended solids, mg/l
 - b. COD or TOC, mg/l
 - c. Nitrogen (total Kjeldahl nitrogen and organic nitrogen), mg/l
 - d. Phosphorus, mg/l
 - e. Alkalinity or acidity, mg/l
 - f. Presence of heavy metals, oils and toxics, etc.

Pretreatment or Primary Treatment

1. If suspended solids are present in excess of approximately 250 mg/l , solids-separation devices such as a sedimentation or flotation may be provided.
2. If oil, grease, or floatables exceed 100 mg/l , a skimming tank or separator should be provided.

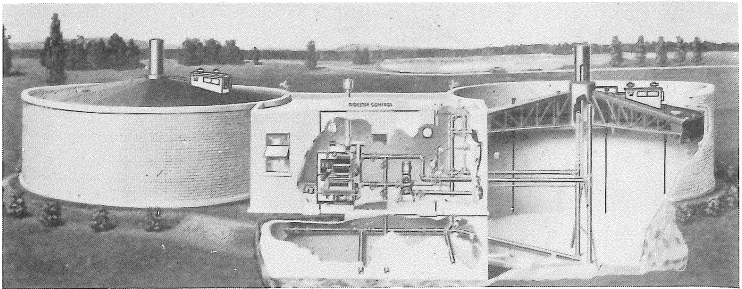


Figure 9.28 Two sludge digestion systems including external heater and gas recirculation for digester mixing. (Courtesy of Pacific Flush Tank Co.)

3. Heavy metals (Cu, Zn, Ni, Pb) should be removed prior to biological treatment.
4. Neutralization of excess alkalinity or acidity should be provided; pH control is critical in the anaerobic process.

Design of the Anaerobic Process

1. Estimate the coefficients a , b , and k of the process for the waste from pilot-plant or laboratory-scale studies (Fig. 9.29).
2. Combining the sludge-growth equation and substrate-removal equation, get a relationship among t , k , a , b , and s_e as follows:

Sludge-growth equation:

$$\frac{s_0 - s_e}{X_a} = \frac{1}{a} + \frac{b}{a} t$$

Substrate-removal equation:

$$\frac{s_0 - s_e}{X_a t} = k s_e$$

or

$$\frac{s_0 - s_e}{X_a} = k s_e t$$