CHAPTER 12

SLUDGE HANDLING, TREATMENT, AND DISPOSAL

12-1. General considerations. Sludge, residual solids, is the end product of wastewater treatment. Primary sludge is from 3 to 6 percent solids. Treatment objectives are reduction in volume and rendering it suitable for ultimate disposal.

12-2. Sludge pumping. Sludges with less than 10 percent solids can be pumped through force mains. Sludges with solids content less than 2 percent have hydraulic characteristics similar to water; this can be assumed for design purposes. For solids content greater than 2 percent, however, friction losses are from 1-1/2 to 4 times the friction losses for water. Both head losses and friction increase with decreasing temperature. Velocities must be kept above 2 fps. Grease content can cause serious clogging, and grit will adversely affect flow characteristics as well. Adequate clean-outs and long sweep turns will be used when designing facilities of these types.

a. Piping. Sludge withdrawal piping will not be less than 6 inches in diameter. Minimum diameters for pump discharge lines are 4 inches for plants less than 0.5 mgd and 8 inches for plants larger than 1.0 mgd. Short and straight pipe runs are preferred, and sharp bends and high points are to be avoided. Blind flanges and valves should be provided for flushing purposes.

b. Pumps. Sludge pumps will be either plunger, progressing cavity, torque-flow, or open impeller centrifugal types. Plunger and progressing cavity pumps generally should be used for pumping primary sludges; centrifugal pumps are more suitable for the lighter secondary sludges. Centrifugal and torque-flow pumps are used for transporting digested sludge in most cases; plunger and progressing-cavity pumps are used when a suction lift is involved.

12-3. Sludge digestion.

a. Aerobic sludge digestion. The major function of sludge digestion (and its principal advantage) is the stabilization of the sludge in terms of volatile content and biological activity. Aerobic digestion accomplishes this through biological oxidation of cellular matter, which is done without the excess production of volatile solids associated with anaerobic digestion. This is accomplished without the production of a high-BOD liquor as results from the production of volatile acids in the anaerobic digestion process.

(1) Modes of operation. Aerobic digesters can be either continuous or intermittent batch operations. With batch operation, waste sludge feed will be discontinued at a specified time before digested sludge withdrawal. In continuous operation, supernatant is

constantly withdrawn. This mode of operation is used when phosphorus is a problem and low phosphorus levels are required in the effluent, because batch operation produces high phosphorus concentrations in the supernatant.

(2) Design factors. A summary of design factors is given in table 12-1. Tank design is open (can be cold-climate problem with mechanical aeration), and no heating is required although some increase in volatile solids reduction can be obtained with increased temperature. Tank design is similar to aeration basin design with the addition of sludge thickening apparatus. A major disadvantage of aerobic digestion is the high energy requirement, with diffused air aeration having the highest, as it requires as much as 100 percent more horsepower than does mechanical aeration.

b. Anaerobic sludge digestion.

(1) Process description. Anaerobic digestion is the predominant method and also usually effective and energy efficient. The process involves gasification, liquefaction, stabilization, colloidal structure breakdown, and water reduction.

(2) Objectives. The objectives of anaerobic digestion are the stabilization of organic solids, sludge volume reduction, odor reduction, destruction of pathogenic organisms, useful gas production, and the improvement of sludge dewaterability. Volatile solids typically are reduced by 60 to 75 percent, with final volatile matter contents of 40 to 50 percent.

(3) Conventional (standard-rate) digestion systems. This type of system will consist of a single- or two-stage process for which tanks will provide for the simultaneous digestion, supernatant separation, and concentration of sludge. The volume will be calculated for a load of from 0.04 to 0.10 pounds of volatile suspended solids per day per cubic foot or for the criteria given in table 12-2. Two-stage processes are more applicable for plants having capacities of more than 1 mgd. The minimum total retention time will be 30 days. For two-stage processes, the retention time in the first stage will be 8 days and in the second, 22 days minimum. The sludge will be heated to and maintained at 95 degrees F., when possible. If sludge heating is not feasible, the tank size will be increased in accordance with local climatic conditions, but not less than twice the volume computed for heated sludge.

Table 12-1. Aerobic Digestion Design Parameters

Parameter	Value	Remarks
Solids Retention Time, days	10-15[a]	Depending on temperature, type of sludge, etc.
Solids Retention Time, days	15-20[b]	
Volume Allowance, cubic feet/capita	3-4	
VSS Loading, pcf/day	0.024-0.14	Depending on temperature, type of sludge, etc.
Air Requirements		
Diffuser System, cfm/1,000 cubic feet	20-35[a]	Enough to keep the solids in suspension and maintain a DO between 1-2 mg/l.
Diffuser System, cfm/1,000 cubic feet	>60[b]	
Mechanical System, hp/1,000 cubic feet	1.0-1.25	This level is governed by mixing requirements. Most mechanical aerators in aerobic digesters require bottom mixers for solids concentration greater than 8,000 mg/l, especially if deep tanks (>12 feet) are used.
Minimum DO, mg/l	1.0-2.0	
Temperature, degrees C	>15	If sludge temperatures are lower than 15 degrees C, additional detention time should be provided so that digestion will occur at the lower biological reaction rates.
VSS Reduction, percent	35-50	
Tank Design		Aerobic digestion tanks are open and generally require no special heat transfer equipment or insulation. For small treatment systems (0.1 mgd), the tank design should be flexible enough so that the digester tank can also act as a sludge thickening unit. If thickening is to be utilized in the aeration tank, sock type diffusers should be used to minimize clogging.
Power Requirement, BHP/10,000 Population Equivalent	8-10	

[a]Excess activated sludge alone.
[b]Primary and excess activated sludge, or primary sludge alone.
Source: EPA Process Design Manual for Sludge Treatment and Disposal, October 1974.

Table 12-2. Standard-Rate Anaerobic Digester Capacity Design Criteria

Feed Sludge Source	Cubic Feet Per Capita
Primary settling only	3
Trickling filter with primary settling	5
Activated sludge with primary settling	6
Imhoff process	4.5

(4) High-rate digestion. The high-rate digestion process differs from the standard-rate process in that the solids loading rate is much greater (up to 4 times), the retention period is lower (one-half), mixing capacity is greater and improved (there is no supernatant, nor thickened sludge produced), and the sludge is always heated. High-rate tanks will be those where the digestion process, accomplished separately from supernatant separation and sludge concentration and storage, includes rapid and intimate mixing of raw and digesting sludge in the entire tank contents with an operating temperature of 95 degrees F. The process will be a two-stage system applicable for treatment plants with capacities greater than 1 mgd and with the primary digestion tank considered the high-rate tank. If sludge drying beds or ponds are to be used for dewatering of the digested sludge, the retention time of the solids in the primary digester will be 15 days. If mechanical sludge dewatering processes are employed, the retention time in the primary digester may be reduced to 10 days. The secondary digester must be of sufficient capacity to provide for supernatant separation and storage of digested sludge. The total volume will be calculated for a load of from 0.15 to 0.40 pounds of volatile suspended solids per day per cubic foot or for the criteria given in table 12-3. The primary digestion tanks will be sized to provide 75 percent of the total design tank volume.

(5) Imhoff tanks. In addition to the removal of settleable solids, anaerobic digestion of these solids is accomplished simultaneously in Imhoff tanks. These units are simple to operate usually consisting of scum removal daily by discharging it into the nearest gas vent; reversal of flow every 2 weeks to even up solids in different ends of the digestion compartment; and drawing off sludge periodically to the sludge drying beds. The tank will be sized based on the per capita figure given in table 12-2. No heating of sludge nor mechanical equipment will be required for the Imhoff tank. The Imhoff tank will be designed such that gas vents are a minimum of 20 percent of the tank surface area. For more information on the settling process of the Imhoff tank, refer to paragraph 8-5. of this manual.

Table 12-3. High-Rate Anaerobic Digester Capacity Design Criteria

Feed Sludge Source	Design Capacity Cubic Feet Per Capita
Primary settling only	2
Trickling filter with primary settling	4
Activated sludge with primary settling	4

(6) pH control. The pH level of the sludge inside the digester is a critical factor in anaerobic digestion, and will be kept as near as 7.0 as possible, with a range of 6.6 to 7.4 considered acceptable. The pH is maintained with bicarbonate buffering and, when natural buffering fails and the pH becomes less than 6.6, hydrated lime (calcium hydroxide) should be added to the digester. Design provisions must be made that will provide a simple means for adding lime to the digester if and when needed. One of the more practical means is to provide for convenient manual addition of lime to the raw sludge pit before the raw sludge is pumped to the digester.

c. Tank element design.

(1) Tank dimensions. No particular shape possesses advantages over all others, but circular tanks are more popular. Circular tanks will not be less than 20 feet, or more than 100 feet in diameter. Side-wall water depths will be a minimum of 20 feet and a maximum of 30 feet. A 2.5-foot freeboard will be provided between the top of the wall and the working liquid level. With mechanisms for removing sludge, the bottoms of the tanks will be flat; otherwise hopper bottoms with steep slopes of 3 feet horizontal to 1 foot vertical will be provided. All tanks designed for treatment plants rated at or above 1.0 mgd will be multiple units.

(2) Covers. Two types of covers are used on sludge digestion tanks, fixed and floating. If a combination of covers is used, fixed covers will be used for the primary stage of a two-stage digestion process and floating covers will be used for the secondary stage. In lieu of floating covers on separate digesters and in cold regions where freezing ice and snow are problems, fixed covers may be used provided a gas collection dome is installed in the top of the cover. At least two access manholes will be provided in the tank roofs. In addition, the tank covers will be provided with sampling wells, pressure and vacuum-relief valves, and flame traps.

(3) Control chamber. A control chamber should be provided for plant operations. Entrance to the control chamber must be designed for the safety of the operator and the equipment. The chamber will be well-lighted, ventilated, and equipped with a water service and drain.

(4) Piping. The particular piping requirements for sludge digesters will include provisions for adding sludge, withdrawing sludge, multi-level supernatant removal points, heating, recirculating sludge or supernatant, flushing, sampling gas collecting, and gas recirculating. All supernatant will be returned to process for further treatment. Supernatant draw-off facilities will be designed to provide variable-rate return to prevent plant upset.

(5) Heating. The method to be used for heating sludge digestion tanks is the circulation of the contents of the tank through a heat exchanger. Heated tanks will be insulated and the heating equipment sized to maintain a temperature of 95 degrees F. during the coldest weather conditions.

(6) Chemical feeding. Practical means for feeding lime or other chemicals that are commonly used to correct digester operational problems must be included as part of the digester design.

(7) Gas collection. Sludge gas will be collected from the digesters either for utilization or for burning it to waste. Two-stage units will provide interconnecting lines permitting transfer and storage from one unit to the other.

(8) Gas utilization. Gas storage facilities will have to be provided if the gas is to be utilized and not wasted by burning. Sludge gas has a heat value of between 500 and 700 Btu/cubic feet. An average gas yield is 15 cubic feet per pound of volatile solids destroyed.

12-4. Sludge storage.

a. Sludge tanks. Sludge storage tanks may have depths no less than 15 feet and bottom slopes of 1 to 4. The tanks may be open or closed. Ventilation must be provided with closed tanks. Decanting lines as well as sludge withdrawal lines must be provided for all tanks.

b. Sludge retention ponds. Sludge retention facilities will be provided at either the treatment plant or land application site. The design detention period will be large enough to compensate for periods when sludge spreading is not feasible but will not be less than 30 days. Storage will permit operational flexibility, additional destruction of pathogens, and further sludge stabilization.

c. Sludge storage ponds. Sludge storage ponds are applicable for storage of well-digested sludge when land area is available. Storage is usually long-term (2 to 3 years), with moisture content being reduced to 50 to 60 percent. Lagoon storage can be used as a continuous operation or can be confined to peak load situations, and serves as a simple and economical sludge storage technique. Land requirements and possible ground water pollution are the major disadvantages.

12-5. Sludge drying. Sludge drying beds rely on drainage and evaporation to effect moisture reduction. These beds are open, and as such are very susceptible to climatic conditions such as precipitation, sunshine, air temperature, relative humidity, and wind velocity. For example, a sludge drying in 6 weeks in the summer would take at least 12 weeks to dry in the winter. Sludge bed drying efficiency can be improved significantly by covering the bed with glass or plastic. Area requirements can be interpreted in terms of the per capita values in table 12-4. These values are very arbitrary and depend largely on climatic conditions. Embankment height will be 12 to 36 inches using concrete, concrete-block, earth or timber walls. Underdrains are to be provided with lateral tiles 12 feet apart and their transported leachate must be returned to the head of the treatment plant. Sand depth will be 9 to 18 inches, with the sand being washed and dirt-free. The sand will have an effective size of between 0.3 to 0.75 mm, with a uniformity coefficient of not more than 4.0. Anthracite coal, pea gravel, and washed grit have also been used as bedding. Sludge distribution can be of various design, although an impervious splash plate of some kind is always provided. Sludge cake removal can be by hand or mechanical means. Bed widths may range from 15 to 25 feet, with lengths of 50 to 150 feet. Multiple beds provide operational flexibility and will be used if appropriate. Sides of enclosed beds will be no higher than 36 inches but will be oriented with the sun such that shading of the sludge is held to a minimum. Open sides, forced ventilation, and artificial heating are enclosed bed modifications. Usually, a combination of open and closed beds performs best in average situations. Odor and insects can be a problem unless the sludge is digested completely. Land requirements and sludge cake removal costs are other disadvantages.

Table 12-4. Area Required for Sludge Drying Beds
(Square feet per capita)

Type of Sludge	Open Beds	Covered Beds
Primary digested	1.5	1.0
Primary and humus digested	1.75	1.25
Primary and activated digested	2.5	1.5

Note: For facilities to be located in regions south of latitude 35 degrees, open bed area requirements may be reduced by 0.5 square feet per capita for all types of sludge and 0.25 square feet per capita for covered beds.

12-6. Sludge disposal. The proper treatment of all residual sludge streams will be provided for in each plant design. The methods of final disposal can be broadly categorized as disposal or utilization procedures. The sanitary landfill and land surface application are, respectively, disposal and utilization methods most suitable for Army installations. The method selected for final sludge disposal or utilization must be in accordance with regulatory agency requirements.

a. Land spreading of sludges. Cropland application and land application are the major sludge utilization methods. The application of sludge to land is economical and simple, but its use may be limited because of the presence of heavy metals in the sludge, public resistance, and the availability of suitable land. In developing a system for the application of either liquid or dewatered sludge to cropland, the mode of transportation, application procedure, and rate of application must be considered.

(1) Transportation. Tank trucks, rail, and pipelines are suitable means for transporting sludge. Sludge characteristics, elevation differences, distance, sludge volume, and land availability are important factors in selecting a method for transporting sludge from the treatment plant to the utilization site. Tank trucks afford flexibility in the selection of utilization sites but their ton-to-mile cost is relatively high. Their use is most feasible where there is available land near the treatment plant. Pipelines are feasible when there is assurance of the availability of land for a long period.

(2) Application procedures. The application of sludge can be accomplished by the following procedures:

(a) Spraying on site.
(b) Gravity flow from tank truck.
(c) Furrowing.
(d) Deep disking.

Furrow irrigation is less objectionable than spray irrigation, which is more visible and which may generate a mist of suspended droplets of liquid that can be blown away from the application areas. The sludge placed deep into the natural soil by burial, deep disking, or rotary tilling, is desirable but not necessary.

(3) Application rates. Sludge composition, soil characteristics, climate, vegetation, and cropping practices will determine the application rate to be used for cropland utilization. It can be assumed that the allowable design application rate of either liquid or dewatered sludge will rarely exceed 20 tons of dry solids per acre per year. Much higher application rates (100 tons of dry solids per acre per year) may be used to reclaim low-quality land, but proper precautions must be taken to prevent or control potential leachate or surface runoff problems. Local representatives of the U.S. Department of Agriculture should be consulted to learn about local soil conditions and their suitability for specific sludge application rates.

b. Landfill disposal of dewatered and stabilized sludge. Most landfills will eventually produce leachate, as well as gases. The quality of leachate depends on the degree of decomposition activity within the landfill. Adequate digestion or chemical stabilization of sludge before disposal to a landfill is essential to avoid poor quality of leachate. To minimize leachate contamination, the landfill operation will be above the high ground water table, and surface runoff from areas tributary to the landfill will be intercepted in drainage ditches to carry it around the landfill. It may be necessary to collect and treat leachate before it reaches a stream or other fresh surface or ground water supply. Prevention of rainfall percolation into the landfill also reduces the pollution potential. This will be accomplished by adequate surface slopes in combination with impervious surface ditches, maintenance of the landfill surface, such as filling settlement areas immediately, and use the planting of cover crop to consume a large volume of water. The use of tight cover material also will decrease the rate of rainfall percolation, but adequate vents must be provided for the gases that are produced in the decomposition process.