CHAPTER 7

SOLIDS HANDLING AND DISPOSAL

7-1. Introduction

a. Most treatment processes normally employed in water pollution control yield a sludge from a solids-liquid separation process or produce a sludge as a result of a chemical or biological reaction. Solids handling and disposal represent 30 to 50 percent of the total cost of treatment. Cost-effective treatment requires efficient solids handling and disposal along with liquid treatment procedures. Process use is limited by sensitivity to the quantity handled, climatological effects, land area and soil constraints, and technological development. Information on proven processes applicable to handling domestic sewage sludge from military installations is presented herein. Industrial wastes may place constraints on the use of some sludge processes and must be evaluated on a case-by-case basis.

b. The ultimate objective in solids handling and disposal methods is to reduce the water and organic content of sludges. These methods include:

–Thickening.
–Digestion.
–Conditioning.
–Dewatering and drying.
–Incineration.

Digestion and incineration are primarily used for the removal of organic matter in sludge while thickening, conditioning and dewatering are primarily used for the removal of water from the sludge. This chapter discusses these methods and describes the application in which they should be used.

7-2. Sludge characteristics

All evaluations of sludge systems should include a detailed mass balance of solids in the system. The mass balance defines the sludge quantities, dry solids content, volatile solids content and extent of recycle or supernatant flow back to the liquid treatment processes, and thus identifies the basis for evaluating different sludge systems.

a. Quantity. The quantity of dry solids produced per day from domestic sewage at military facilities will generally range as shown in table 7-1. Variations in primary sludge quantities are due to the type of collection system, i.e. combined systems yield more grit and other suspended material which require solids handling. For secondary sludges, all of the activated sludge systems generate the higher values except extended aeration which produces very low quantities. Most treatment plants at military installations are trickling filters and sludge from the final clarifiers is routinely returned to the primary settling tanks for subsequent solids withdrawal. Thus, the combined primary-secondary sludge quantities in table 7-1 are most appropriate and should be used for planning purposes. When chemical precipitation methods are employed for phosphorus removal or other purposes, the solids shown in table 7-1 will increase to a level dependent on the type and quantity of chemical addition and the chemical characteristics of the raw wastewater. The quantity of chemical sludge must be estimated for each application and, in most instances, will warrant bench testing prior to facility design.

Table 7-1. Typical raw sludge quantities

Sludge Type	Dry Solids Per Day lb/capita
Primary Sludge	0.12-0.20
Secondary Sludge	0.05-0.20
Combined Primary & Secondary	0.17-0.40

b. Volatility. The volatile solids content of undigested primary and/or secondary sludges is 60 to 80 percent. The volatile solids loading is particularly important for sizing digesters.

c. Specific gravity. The specific gravity of the dry volatile solids is about 1.0 and dry fixed solids about 2.5. The specific gravity of a particular mixture of sludges depends upon the relative fraction of volatile solids. Most wet raw sludges have a specific gravity ranging from about 1.01 to 1.03.

d. Solids content. The percent dry solids of fresh sludges drawn from clarifiers range as shown in table 7-2. Sludges can be efficiently pumped when the dry solids content is under 5 to 6 percent. Most sludges over 10 percent dry solids content must be transported as a semi-solid using such equipment as conveyor belts.

Table 7-2. Typical raw sludge solids content

Sludge Type	Solids Content (percent dry solids by weight)
Primary	2.5-5.0
Trickling Filter	5.0-8.0

Table 7-2. Typical raw sludge solids content–Continued

Sludge Type	Solids Content (percent dry solids by weight)
Combined Trickling Filter and Primary	3.0-6.0
Activated Sludge	0.5-1.5
Combined Activated and Primary	3.0-5.0

7-3. Conditioning and stabilization

For most military installations, disposal of sludge in landfills or on the land will be cost-effective and must be utilized. The rare exceptions are areas where incineration can be justified by the excessively long hauling distances required for reaching an acceptable disposal site or by the presence of industrial wastes that preclude land disposal. These land disposal methods require some previous stabilization step to avoid environmental degradation.

a. Anaerobic digestion. Anaerobic digestion, although sometimes difficult to control, is a very desirable and proven stabilization step. It conserves energy when the system produces a combustible gas that can be used for sludge heating and for other purposes. The process will function well in most climates and renders a stabilized sludge. For military installations, anaerobic digestion shall be used unless highly variable solids loads are expected or unless local factors justify use of alternative processes. The most important factor for sizing digester capacity is the volatile solids loading. TM 5-814-3 should be referred to for acceptable design criteria.

b. Aerobic digestion. Aerobic digestion is a stabilization process applicable to facilities where blowers are installed or are required for the liquid treatment operations. Since most military plants do not have blower systems, aerobic digestion will not be feasible. Other disadvantages are high power requirements and low efficiencies for military installations located in extreme northern climates. Aerobic digestion may have application at small package plant facilities or where wide load variations cause difficulties with anaerobic digestion.

c. *Thermal conditioning. "Cooking"* sludge under elevated temperature and pressure is a thermal conditioning and stabilization process receiving more attention in the U.S. It eliminates chemicals needed to condition a sludge prior to dewatering and also increases dewatering rates. Disadvantages are that it is a fuel consumer unless heat recovered from a combustion process is available, and supernatant recycle flows can add 15 to 30 percent additional BOD load on the liquid treatment system. Generally, thermal systems are only practical for larger plants, greater than 10 mgd, or for special applications where high bacteriological kills are necessary for land disposal.

d. Chemical conditioning. Where mechanical dewatering is utilized, some form of chemical conditioning is common. Most plants find that lime and/or ferric chloride produce the best results and are most economical. Where disposal of nondigested sludges occur, high lime treatment (pH of 11.5 for over 2 hours) will render a stabilized sludge. Lime, unlike ferric salts, is a bactericide which assists in treating the sludge.

7-4. Thickening

Most military facilities recycle secondary sludges to the primary tanks. Since most plants are trickling filters, the resulting sludge mixture is in the 5 percent dry solids range and thickening is therefore not warranted. At new activated sludge installations, thickening may be necessary due to the low solids content; flotation will usually be cost-effective for these applications. Gravity thickening is appropriate for combined sludges.

a. *Gravity.* Gravity thickening is accomplished in a tank equipped with a slowly rotating rake mechanism that breaks the bridge between sludge particles, thereby increasing settling and compaction. The primary objective of a thickener is to provide a concentrated sludge underflow. The design of a mechanical thickener is generally based upon a solids loading rate. Typical solids loading rates are in the range of 10 to 30 lbs/sq ft/day. Gravity thickeners should be designed to maintain aerobic conditions in the unit. Anaerobic conditions may cause floating sludge and odor problems with the unit. Thickener performance can be improved by the addition of coagulant to the influent feed. Polyelectrolytes are the most common type of coagulant aid used in thickening.

b. Dissolved air flotation. Thickening through dissolved air flotation is becoming increasingly popular and is particularly applicable to gelatinous sludges such as activated sludge. Flotation thickeners can be loaded at higher levels than gravity thickeners because of a more rapid separation of the solids from the sewage. Loadings are typically in the range of 10 to 55 lbs/sq ft/day depending on the sludge and the degree of conditioning. In flotation thickening, small air bubbles released from solution attach themselves to and become enmeshed in the sludge floes. The air-solid mixture rises to the surface of the basin, where it concentrates and is removed. The primary variables are recycle ratio, feed solids concentration, air-to-solids (A/S) ratio, and solids and hydraulic loading rates. Air pressures between 40 to 60 psi are commonly employed. The recycle ratio is related to the air-to-solids ratio and the feed solids concentration (72). Experience has shown. that in some cases dilution of the feed sludge to a lower concentration increases the concentration of the floated solids. The use of polyelectrolytes will usually increase the solids capture and the thickened sludge concentration.

c. *Centrifuges.* Centrifugation is employed both for the thickening and the dewatering of sludges. The process of centrifugation is an acceleration of the process of sedimentation by the application of centrifugal forces. There are three types of centrifuges available; the solid bowl, the basket type and the disc-nozzle separator. The basic difference between the types of centrifuges is the method in which solids are collected in and discharged from the bowl. Sludge solids settle through the liquid pool and are compacted by centrifugal force against the walls of the bowl and are then conveyed by the screw conveyor to the drying or beach end of the bowl. The beach area is an inclined section of the bowl where further dewatering occurs before the solids are discharged over adjustable weirs at the opposite end of the bowl (80) Typically, centrifuges can thicken an activated sludge to a concentration of 5 to 10 percent without chemical addition.

7-5. Dewatering

a. Drying beds. When stabilized sludge is deposited in a wet condition on the land, no dewatering is practiced. For facilities that require dewatering prior to disposal and have sufficient land area, drying beds are cost-effective and should be used. Usually drying beds will be feasible up to plant capacities of about 1 mgd. Sufficient storage should be provided in digesters to allow operational flexibility.

b. Vacuum filters. Vacuum filtration is the most widely applied mechanical dewatering method in the U.S. This method is well established for removing moisture from sludge and can achieve from 15 to 25 percent solids concentration in the cake after dewatering. Vacuum filters shall be used for mechanical dewatering unless other methods are cost-effective for special applications.

c. *Belt presses.* The belt press is a recently developed piece of dewatering equipment that presses sludge between two porous belts that forces water from the sludge through compression. The pressing operation is continuous and is usually preceeded by a chemical addition phase where flocculants are added to improve the dewatering characteristics of the sludge. With the proper conditioning, belt presses can achieve a cake solid in the 20 to 30 percent range for activated sludge and up to 35 to 40 percent cake solids for metal hydroxide sludges.

d. Plate presses. Filter presses are an alternative to vacuum filters and belt presses. Filter presses have higher capital and operating costs than either of the previous alternates, but produce a drier cake (solids concentrations in the range of 25 to 40 percent). These units may be desirable at some installations to minimize fuel requirements when a combustion process follows or to reduce haul costs when long distances are involved.

7-6. Incineration

Sludge incineration reduces the volume handled in the transportation and ultimate disposal steps and sterilizes the residue. High investment and operating costs, and stringent air pollution criteria are significant considerations in determining the need for incineration. Fuel is also a factor and without sufficient dewatering (to at least 35 percent solids) the furnaces will be energy consumers. Rarely has incineration been used at military treatment facilities and it shall be evaluated only for special applications or land scarce areas. Fluidized bed furnaces may be considered for some industrial wastes. Multiple hearth units are predominantly used to burn sewage sludge. Mixing sludge with refuse for burning takes advantage of the net heat generated by refuse combustion.

7-7. Other processes

Many other sludge handling, processing and disposal operations have been tried and are in use at other than military installations and some processes are currently in the technical development stage. These include pyrolysis, heat drying, comporting, freeze dewatering, drying lagoons, rail and barge transport systems, fertilizer production and others. Most of these are not practical or feasible for military facilities. Authority to deviate from using the proven processes presented in this section must be obtained from HQDA (DAEN-ECE-G) WASH DC 20314.

7-8. Solids handling process comparisons

Table 7-3 presents a general comparison of the sludge unit processes which may be considered for military facilities. These comparisons of preliminary treatment steps, applications, resource consumption, operations and other factors are merely to summarize typical applications. Local factors will, of course, cause some exceptions.

Table 7-3. Summary of solids handling and disposal

Unit Processes	Purpose	Major Equipment Required	Preliminary Treatment Steps	Application
A. Thickening	Reduce volume handled in subsequent steps by removal of water.	Gravity or flotation equipment, tanks, usually covers for flotation.	None.	All plant sizes and sludge types. Usually not used for military plants since trickling filter sludges predominate which are returned to the primary.
9. Anaerobic Digestion	Biologically stabilizes and transforms sludge into a material suitable for disposal on the land.	Tanks, covers, gas collection equipment, heat exchangers, and mixing equipment.	Sometimes thickening.	All plant sizes. Is particularlydesirable for military installation.
C. Aerobic Digest on	Biologically stabilizes and transforms sludge into a material suitable for disposal on the land.	Tanks and aeration equipment.	Sometimes thickening.	Usually plants under 15 to 20 mgd.
D. Thermal Conditioning/ Stabilization	Thermally conditions sludge for dewatering without chemicals and-stabilizes the material by heat disinfection for subsequent land disposal.	Thermal reactor, steam generating equipment, heat exchangers, sludge, grinder, pumps and piping, and decant tanks.	Must have a thickened sludge for economical operation.	Usually economical for plants larger than 10 mgd.
E. Sludge Drying Beds	Reduces the sludge moisture content for easier handling in final disposal, changes sludge from a liquid to a semi-solid.	Land, sand and gravel beds, and underdrain system.	Must have digestion to avoid odors.	Usually plants under 1 mgd. Limited to areas which have sufficient land.
F. Mechanical Dewatering	Reduces the sludge moisture content for easier handling in final disposal, changes sludge from a liquid to a semi-solid.	Filter units, pumps, piping, conveyor equipment, chemical conditioning facilities, and building.	Digestion, thermal conditioning or chemical conditioning, usually thickening.	May be used for raw or digested sludges. Equipment selection dependent on means of disposal
G. Sludge Incineration	Reduces hauling and final disposal land requirements. Provides acceptable material for disposal.	Furnaces, feed and air blower equipment, ash handling equipment, and air pollution control	Dewatering.	Mainly for very large plants (over 10mgd) in metropoliton areas where land is extremely scarce and costly.
H. Landfill	Dispose of sludge solids under soil cover in an envirornmentally acceptable manner.	Land and landfill equipment.	Stabilization and dewatering	All plant sizes.
I. Land Spreading	Disposes of sludge solids on the land in an environmentally acceptable manner.	Land, pumping, piping, storage ponds, mixers, and spray equipment for liquid sludge; or tractors, and solids storage and spreading equipment for dewatered sludge.	Stabilization.	May be used for either liquid or dewatered sludges. Applicable to all plant sizes. Some limitations for cold climates.

Table 7-3 (Cont'd). Summary of solids handling and disposal

	Performance	Economics	Resource Consumption	Operation	Side Streams	Aesthetic Problems
A.	Increases solid content to the 4 to 6 percent range	Flotation is usually lower in capital but higher in operating.	Lower power use; flotation is higher than gravity.	Flotation requires closer operator attention, particularly if chemicals are used.	Supernatant or subnatant return must be considered in design.	Potential odors if improperly operated.
B.	Digested sludge readily dewaters and is stabilized for subsequent disposal.	Relatively high capital costs.	Produces combustible gas for the process and other uses; also produces a soil conditioner.	Requires close operator attention; subject to upsets with wide variations In load.	Supernatant return must be considered in design.	Improperly operated units will produce odors.
C.	Digested sludge sometimes difficult to dewater. Stabilized sludge for subsequent disposals.	Lower capital costs than anaerobic digestion, but operating costs are higher.	Higher energy use than anaerobic digestion.	Relatively free of upsets Poor operation in cold climates. Simpler operation than anaerobic digestion.	Surpernatant return must be considered in design.	Improperly operated units will produce odors
D.	Eliminates use of chemicals for conditioning. Stabilizes sludge for land disposal. Improved cake moisture.	High capital and operating costs.	Large fuel use.	Skilled labor required	A major portion of the sludge is resolubilized and is returned as a supernatant. This load must be considered in the liquid treatment facilities design loading.	Odors may result with improper operation.
E.	Proper dewatering can be accomplished, but is usually difficult to control since it is weather dependent.	Usually lower costs than mechanical dewatering until large areas are required.	Minimal power or chemical use. Large land usage.	Normally poor winter operation.	Underdrainage must be returned to the plant.	Potential odors.
F.	Sludge cake solids content: vacuum filter 15 to 25 percent; belt press 20 to 30 percent; filter press 25 to 40 percent.	High capital and operating costs.	Power use high. Small land area used.	Nearly continuous operator attention required.	Filtrate return must be be considered in design.	Odors for personnel working in building with equipment.
G.	Renders a sterile ash which can be readily disposed of on the land. Air pollution control can be a problem.	High capital and operating costs.	Large fuel use. Disregards other beneficial uses of the waste solids.	Skilled operators required.	Air emissions must be controlled, scrubber water return must be considered	Potential odor and particulates from exhaust gases If not properly operated.
H.	Suitable disposal technique with proper facility siting and operation.	Moderate costs. Dependent on land values in the specific area.	Minimal fuel and land use.	Mixing with refuse is desirable for efficient operation.	None unless material is improperly stabilized or landfill is not properly located or operated.	Potential odors If improperly operated.
I.	Suitable disposal techniques with proper facility siting and operation. Careful control of application rates and other factors are particularly important for liquid sludge.	Moderate costs. Oependent on land values in the specific area.	Minimal fuel use. Moderate power use with liquid spreading. High land use, but solids used beneficially as a soil conditioner.	Winter storage facilities are needed in cold climates. Application to the land is quite dependent on crops, soils, and weather.	None unless material is Improperly stabilized or applied.	Potential odors if improperly operated. Use of large land areas for sludge disposal may be a problem in some areas.