Forest Service Handbook
National Headquarters - Washington Office
Washington, DC

Forest Service Handbook 7409.11 – Sanitary Engineering and Public Health Handbook

Chapter 50 - Wastewater

Amendment: 7409.11-Amendment-10

Effective date: October 1979

Duration: This amendment is effective until superseded or removed.

Superseded Directive:

Approved by:

Date approved:

Responsible Staff:

Explanation of changes:

Table of Contents

57.3 - Nutrient Removal

In the context of most wastewater treatment situations, the reference to nutrients includes nitrogen and phosphorus. This is because these two elements are generally the limiting growth factors in the natural environment, and their addition greatly enhances proliferation of aquatic plants. If discharge streams do not contain significant nutrient contributions, then, supposedly, the receiving waters will remain in near natural state. This is generally true for fresh water environments, but in salt or brackish waters, carbon, rather than nitrogen and phosphorus, is thought to be the limiting element.

In the treatment of domestic wastewaters, the removal of nitrogen and phosphorus is usually necessary to meet discharge requirements under the best practical treatment regulations. However, in the treatment of certain industrial wastes which are high in carbohydrates, it is often necessary to add either or both nitrogen and phosphorus to achieve the chemical balance necessary for the bacterial growth required for the treatment process.

57.31 - Phosphorus Removal

Phosphorus occurs in domestic wastewaters in three forms; orthophosphates, polyphosphates, and organic phosphate compounds. The latter generally decompose to orthophosphates while the polyphosphates are converted to the ortho form. This is fortunate because, in this state, phosphorus is most easily precipitated.

Phosphorus can be removed by both biological or chemical means or a combination of the two. In the growth phase, bacteria accumulate phosphorus, some strains to a much greater degree than others. These bacteria, when contained in an anoxic state (without oxygen but not anaerobic) release the accumulated phosphorus to a large degree. The biological method uses this characteristic by holding the biomass in a holding tank without air supply for a period of 4-6 hours. The liquid is decanted and disposed of where the contained phosphorus will not have an adverse effect. The settled sludge is returned to the aeration tank where it has an enhanced effect because of its previous deprivation.
In the chemical-biological method, which is patented as the PhoStrip process, the decanted liquid goes to a mixing tank where lime is added to precipitate the phosphorus. The sludge goes to dispoal while the decant from the lime reactor may be used to elutiate the sludge in the anoxic tank or may be sent back to the headworks. In this process, the anoxic tank is called the stripper tank.

The chemical removal of phosphorus is accomplished by precipitation induced by the addition of alum, lime, or iron salts. The latter are usually ferrous sulfate, ferric sulfate, or ferric chloride. Pickle liquor from metal finishing plants has also been used as an additive. When added ahead of the primary clarifier, alum, lime, or iron salts can be used; when added to the aeration basin, from salts or alum are used.

When combined with biological processes, removal efficiencies can be expected in the 75 to 85 percent range. These can be increased to 93 or 94 percent with filtration. Chemical coagulation and filtration of the secondary effluent can reduce phosphorus content of domestic wastewater to 0.10 mg/l or less.

When chemicals are added to the wastewater to precipitate the phosphates, the amount added is dependent on (1) their concentration in the case of alum and iron salts addition, and (2) pH in the case of lime. When added to the mainstream, this can require a considerable amount of coagulant, and in the case of lime, means for its recovery are usually provided in the larger installations. Lime recovery is accomplished by the addition of carbon dioxide in a 2-stage process. The first partially adjusts the pH downward an precipitates calcium oxide, which is recalcined to lime; the second adjusts the pH to near neutral. When accomplished in a single step, the calcium is not precipitated, recovery is not possible, and the hardness of the effluent may well be excessive.

If the process is arranged to keep chemical and biologic sludges separate, several advantages are apparent. Recovery of lime is rather uncomplicated, interference with biologic process is avoided, and chemical sludges can be recirculated to the mixing basins to increase the efficiency of their operation.

57.32 - Nitrogen Removal

The prevalence of nitrogen in the environment is partly due to the many forms in which it can appear. This is because its states of oxidation can vary from those having an electron charge of -3 to those of +5. Common forms represented in wastewaters are nitrogen gas, ammonia, ammonium compounds, nitrates, nitrites, urea, an organic nitrogen. Organic nitrogen is protein an is converted to the ammonium form (NH3/NH4) through the action of micro-organisms. The process is reversible and ammonia is hydrolyzed to ammonium carbonate by the enzyme urease through photosynthesis. Ammonium is nitrified first to nitrite and then to nitrate by bacterial action. Nitrites (NO2) are oxidized by bacteria to nitrates (NO3) which can be successively reduced to nitrites and nitrogen gas in the presence of organic carbon.

The role of nitrogen in wastewaters as a nutrient or biostimulant is often stressed, but it is important for other reasons as well. It significantly reduce the effectiveness of chlorination since the oxidation of nitrogen compounds exerts a chlorine demand. In the ammonia form, it can be toxic to fish in the receiving waters. Both nitrates and nitrites in drinking water are a public health hazard and can produce methemoglobinemia or "blue babies" in infants less than 3 months old. For industrial use, waters containing ammonia are corrosive, and this and other forms of nitrogen promote the formation of growths in cooling towers and other equipment.

The major means of nitrogen removal now employed include ammonia stripping, nitrification-denitrification, selective ion exchange, and superchlorination.

1. Nitrification-Denitrification. Treatment processes where the ratio of BOD5 to ammonia nitrogen is high combine carbon oxidation with nitrification. In these cases, the concentration of nitrifying bacteria is relatively low, and nitrification is accomplished at a low rate, the majority of the oxygen demand being used for the oxidation of organics. Extended aeration is an example of this situation.

If the BOD5 is reduced, the proportion of total nitrogen to BOD5 is increased, the population of nitrifiers increases, and the nitrification process proceeds at a higher rate. Denitrification can then be accomplished

by the addition of organic carbon with the release of nitrogen gas. Oxidation of the carbon provides the energy for bacterial action, but this may occur using either oxygen or nitrate for the oxidation. Since the bacteria prefer oxygen if it is present, the utilization of nitrate for denitrification can occur only if anoxic conditions exist. The carbon source most often mentioned is methanol, but other sources, including wastewater effluent, can also be used with varying degrees of success.

Fine grain filters or packed towers may also be used for the denitrification process. The media provides a place of attachment for denitrification bacteria in an anoxic environment. A carbon source is added with similar results to that obtained in the conventional suspended growth processes. In the case of filters, liberated nitrogen gas must be flushed out during backwash.

The Bardenpho process combines nitrogen and phosphorus removal by impressing successive aerobic and anoxic conditions on the wastewater and its bacterial population. The resulting stress frees the phosphorus as previously described while the anoxic conditions result in the removal of nitrogen in the conventional manner.

2. Selective Ion Exchange. Conventional ion exchange resins are generally unsuitable for the removal of nitrogen because they have a preference for ions other than ammonium or nitrate. A natural resin, clinoptilotite, has proven successful in removing ammonium ions. Nitrate, nitrite, and organic nitrogen are unaffected. The natural resin in ground usually to a 20x50 mesh for use in the exchanger. Larger sizes are less effective in nitrogen removal while smaller sizes induce too great head losses. Removals of 90-95 percent can be expected.

After a volume of wastewater equivalent to 120-150 bed volumes of the resin has been processed, the bed must be regenerated. This is done by passing a salt solution through the exchanger in the conventional manner. However, in this case, the regenerant can be reclaimed for reuse. Three methods are in use: air stripping, steam stripping, and electrolytic treatment. The method depends on the pH of the regenerant used. As in other ion exchange processes, it is important to filter the influent to the exchanger to prevent fouling of the resin.

3. Ammonia Stripping. This process is effective in removal of molecular ammonia (NH3) only; it is ineffective for nitrates, nitrites, or organic nitrogen. By raising the pH of the wastewater to 10 or 11 with the addition of lime, ammonium ions are converted to molecular ammonia. Spraying the wastewater in fine droplets in ammonia-free air releases the ammonia because of the difference in partial pressure of ammonia in the air and in the droplets. The process is ineffective in cold weather, and the deposits of calcium carbonate can present a problem.

The latter problems are eliminated by a stripping process developed by Ch2M/Hill Consulting Engineers. In their process, an absorption unit is used which is similar to the stripping tower except an absorbing liquid is used to remove the ammonia from the airstream. The latter is recirculated rather than being exhausted to the atmosphere. Since outside air is not used, icing is prevented, and the absence of carbon dioxide eliminates the formation of scale.

4. Supercholorination. This is also breakpoint chlorination and use chlorine to oxidize ammonia nitrogen to nitrogen gas. Supposedly, it takes 10 mg of chlorine to oxidize 1 mg of ammonium, but this is not particularly helpful because the cholorine must first oxidize the organic nitrogen. Its effect on the latter is not definite, and conflicting reports appear in the literature.

The oxidation of ammonia nitrogen also produces one hydrogen ion for every ammonium ion oxidized. This increases the acidity, and it is usually necessary to add line to neutralize the effluent. This increases the total solids and the cost considerably. Dechlorination is also usually required.

57.4 - Dissolved Inorganics Removal

Heavy metals present in wastewater are generally the contribution of industrial discharges, although traces may well be present in some natural waters. In the past, recreation travel trailers have used zinc sulfate as a bactericide in their holding tanks. EPA has recommended this chemical compound not be used, and it is being replaced by formaldehyde. Problems with treating zinc in the wastes from trailer dump stations should be reduced or eliminated. Other inorganics are usually various salts which are seldom of concern in wastewater treatment except where recycle or groundwater recharge is contemplated.

Membrane processes, such as reverse osmosis, and electrodialysis, and exotic processes, such as eutectic freezing and distillation, are not considered practical at this time for wastewater treatment. All have capital costs too high to be economic in most instances; the membrance processes are easily fouled by organics an require excessive maintenance and/or extensive pretreatment. Operating costs for all of them are also very high except for distillation when accomplished naturally. In this instance, large land areas are required, and operation can only be seasonal in most parts of the country.

Metals are most commonly removed by raising the pH of the wastewater which precipitates the metals as oxides or hydroxides. The sludge is concentrated and removed for disposal or reclamatioin while the decant is filtered to remove remaining suspended solids. Experimental work has been done on the use of ozone for metals removal, and this holds promise in that it is often effective in oxidizing chelated metals which resist treatment by the conventional method.

Since the addition of lime for pH adjustment is not uncommon and is used in conventional treatment for nitrogen and phosphorus removal, many dissolved metallic compounds are precipitated in the process. Often, industrial discharges are required to be pretreated for metal removal prior to discharge to the municipal or regional system, or at least the penalties are such that pretreatment is the economical solution. Also, as previously mentioned, activated carbon is effective in the removal of many metals. Tertiary processes containing activated carbon for other purposes can remove metals as well.

Although many reclamation systems are planned which contain both activated carbon and ion exchange for demineralization, few wastewater treatment systems presently include the latter. When ion exchange is used for demineralization, there are usually two exchangers employed. One contains an

acid resin which is regenerated with acid, and the other a base resin which is regenerated with caustic. The water regenerants may be blended to adjust the pH, but disposal sometimes poses a problem.

Resins are available which are rather selective in their action. The system must be custom designed for each wastewater application.

58 - Sludge Handling and Disposal

The solids removed from wastewater plants include grit, screenings and sludge. Of these, sludge is the largest in volume. Its processing and disposal may be the most complex problem facing the engineer in the field of wastewater treatment. The problems of dealing with sludge are complicated because (1) it is composed mostly of the substances responsible for the offensive character of raw sewage; (2) sludge will decompose and become offensive; and (3) only a small part of sludge is solid matter. The main purpose of this section is to delineate the operations and processes that are used to reduce the water and organic content of sludges and to identify safe methods for final disposal of the treated sludge. Sludge handling processes can be classified as shown in exhibit 1. Within each of the categories there are numerous process alternatives.

58.1 - Sources, Quantities, and Characteristics

58.11 - Grit

The quantities of grit produced will vary greatly from one location to another depending on the type, materials, design, construction and condition of the collection system, the characteristics of the drainage area, the number of garbage grinders on the system, and similar variables. The quantity of grit removed from municipal wastewaters may range from 1/3 cu. ft/million gallons treated to as much as 24 cu. ft/million gallons. Although no investigation has been directed toward quantifying the volume of grit which would be associated with vault toilet wastes, a single report does indicate that approximately 1/10 cubic foot/1000 gallons of undiluted wastes may be a reasonable estimate.

Due to the organics mixed in with the grit, the grit is putrescible. The common test for ascertaining the nuisance value of grit is the Dazey churn test which is, in itself, a very inconclusive test. It is generally accepted that a grit of less than 5 percent putrescibility as determined by the Dazey churn test is satisfactory for ordinary disposal (landfill).

58.12 - Screening

The removal of coarse solids by bar screens is frequently the first step in a treatment process. The items removed are generally 1/2 inch and larger. Systems with treat pumped wastes from vault and pit toilets will find a substantial volume of inorganics removed by this process. These will include cans, bottles, rocks, plastic diapers and bags, clothing, and similar items.

The quantity of screenings removed by bar racks in municipal systems usually varies from about 0.5 to 5.0 cu ft/million gallons of wastewater treated; the average is about 2 cu. ft/million gallons. Although they are not commonly found at the head of treatment processes, fine screens (approximately 1/8

inch slots) should be expected to remove 5 to 30 cu ft/million gallons from the same type wastewater.

An investigation of vault toilet contents indicates that undiluted vault toilet wastes may add approximately 1/10 cu ft/million gallons to the quantity of screenings.

Screenings will trap some sewage organics and are putrescible. There are no tests suitable for determining the nuisance value of screenings.

Screenings are usually disposed of in sanitary landfills without further treatment. They will not be addressed further in this section.

SEE PAPER COPY FOR EXHIBIT 1

58.13 - Sludge

The various wastewater treatment processes produce different amounts and types of sludges. The following table presents data on typical volumes of sludges produced in several conventional treatment processes.

A 1,000 gallon of vault toilet wastes, when discharged from the pumper truck into the treatment plant, has approximately the same BOD and SS content as a million gallons of municipal waste. Each 1,000 gallon load of vault toilet waste should, therefore, be expected to produce sludge at the same rates as shown in the table for a million gallons of sewage.

SEE PAPER COPY FOR TABLE

58.2 - Grit Removal and Disposal

The simplest method of grit removal, by shovel and wheelbarrow, is used in very small plants. A block and tackle suspended from a swinging boom is occasionally used in slightly larger plants.

As grit is removed from the chamber, it is placed in a location where free moisture can drain from the grit back into the treatment system. The drained grit is generally disposed of at a landfill without further treatment; the treatment methods described in the remainder of this section are not applicable to grit.

In most cases, grit chamber design is based on removing particles 0.2 mm (65 mesh sieve) and larger with an average specific gravity of 2.65. This appears to be adequate; however, systems in fine-grained soils should expect a finer grit and should be designed accordingly. In addition, many cases of grit having specific gravity values substantially less than 2.65 have been reported. It is important to recognize the extreme variations in grit volume and quality that may be experienced. It is suggested that a generous safety factor be employed in calculations involving the actual storage, handling and disposal of grit.

58.3 - Thickening

The term thickening is used to describe an icrease in solids concentration by partial removal of the liquid portion. The purpose of thickening is to:

1. Reduce the volume of sludge to be stabilized, dewatered, or hauled away as a liquid for final disposal.

2. Improve efficiencies of the sludge treatment processes to follow.

3. Blend primary and sewage sludge.

Thickening process are:

Gravity.
Flotation.
Centrifugation.

Thickening may occur as the objective of a separate process or as a secondary effect of a process provided for a different purpose. During sludge handling, this process frequently occurs more than once. Individual unit processes that afford sludge thickening are summarized in the following table.

OCCURRENCE OF THICKENING IN WASTEWATER TREATMENT PROCESSES

Unit Process	Principal Functions
Primary Sedimentation	Clarification-liquids sometimes blend and/or thicken sludge
Elutriation Basin	Wash and thicken sludge
Secondary Sedimentation	Clarification-liquids partially thicken sludge
Gravity Thickener	Thicken and blend sludge

Gravity thickening of raw or digested primary sludge is almost always an efficient and economical process. Anaerobically digested primary sludge is normally thickened by gravity in the secondary digester. The use of primary basins to capture and thicken both wastewater influent and recirculated excess activated sludge (EAS) solids has been found to be poor practice. The EAS solids do not resettle well in the primary, and this results in the production of more EAS due to an increased load on the aeration system. Further, relatively poor thickening results when the primary basins happen to capture some of the EAS solids. Because the gravity thickeners process mixtures of raw primary and air system excess activated sludges inefficiently and only provide marginal solids capture, they are infrequently used at this time.

Elutriation had been regarded generally as a means for reducing the demand for acidic chemical conditioner by washing out the fine solids an alkalinity. It is now normally used also to thicken combined primary and secondary sludges after anaerobic digestion. Such thickening is accomplishd with lower volumes of wash water and polyelectrolyte addition. In fact, elutriation is

now well recognized as a post-digestion gravity thickening process. This is not commonly employed in small systems.

Use of dissolved air flotation for thickening of EAS has increased because it gives reliable and effective results. Centrifugal thickening of EAS has not yet been widely applied. Recent improvements, however, in the design of solid bowl conveyor units and disc units may alter this situation. These are not usually found in small systems due to the required maintenance.

58.31 - Gravity Thickener

Gravity thickeners are available in two geometric configurations - circular and rectangular. Circular clarifiers are available with two basic flow patterns - center feed and periphera feed. Circular clarifiers are the most common in this country and the peripheral feed has been proven to be the most efficient of the flow patterns with regards to solids removal.

Typical solids loadings, as well as thickener output concentration for various sludge types, are shown in the following table.

GRAVITY THICKENER SURFACE
LOADINGS AND OPERATIONAL RESULTS

Type of Sludge	Solids- Surface of Loading (lb/day/ft2)	Thickened Sludge Solids Concentration (%)
Separate sludges		
Primary	20-30	8-10
Modified activated	15-25	7-8.5
Activated	5-6	2.5-3
Trickling filter	8-10	7-9
Combined sludges		
Primary and modified activated	20-25	8-12
Primary and activated	6-10	5-8
Primary and trickling filter	10-12	7-9

This data should be viewed carefully since:

No data on quality of thickener overflows is presented and both loading and the degree of thickening accomplished would influence this.

Achievement of only 2 to 3 percent solids in the gravity thickening of activated sludge further shows the inadequacy of this method for such sludges.

Data on combined sludges is reasonable, except that few plants attain a 5 to 8 percent thickened sludge solids concentration with a mixture of primary and activated sludges.

58.32 - Air Flotation Thickening

In general, air flotation thickening can be employed whenever particles tend to float rather than sink. These procedures are also applied if the materials have a long subsidence period and resist compaction for thickening by gravity, such as excess activated sludge (EAS).

Flotation thickening units as reviewed by Culp are becoming increasingly popular for handling excess activated sludge since they have the advantage over gravity thickening tanks of offering higher solids concentration (4-6%) and a lower initial equipment cost. In spite of this, air flotation units are infrequently used in smaller systems due to the level of maintenance required.

Flotation, which uses rising gas bubbles to increase the buoyancy of solid particles, is accomplished in four ways:

1. Dispersed air flotation occurs when bubbles are generated by introducing air through a revolving impeller or pourous media.

2. Dissolved air-pressure flotation occurs when air is put into solution under elevated pressures an later released at atmospheric pressure.

3. Dissolved air-vacuum flotation occurs when a vacuum is applied to wastewater aerated at atmospheric pressure.

4. Biological flotation occurs when the gases formed by natural biological activity are used to float solids.

Of the preceding techniques, dissolved air-pressure flotation enjoys by far the widest usage in the United States.

The objective of flotation-thickening is to cause the solids to separate from the water in an upward direction by attaching minute air bubbles to particles of suspended solids. The solid particles with attached bubbles have a specific gravity lower than water and tend to float. The bubbles formed must have a small diameter. This is accomplished by releasing air from a solution that has been pressurized at 40 to 80 psi. Since the solubility of air increases with pressure, substantial quantities of air can be dissolved. In modern flotation practice, two general approaches to pressurization are:

Air charging and pressurization of dilution water (frequently recycled clarified effluent) with subsequent addition to the feed sludge.

Air charging and pressurization of the combined dilution liquid and feed sludge.

Release of the pressurized flow into a chamber at near atmospheric pressures decreases solubility of air, and the excess comes out of solution to form minute air bubbles (average diameter 80 microns). These attach themselves to and are enmeshed in particles of flocculated sludge.

There are several manufacturers of dissolved air flotation (DAF) systems used for wastewater sludge thickening. Three widely used systems in the United States are those manufactured by (1) Komline-Sanderson, and (2) Rexnard, and

(3) Envirotech. Additional information regarding DAF units and design criteria can be obtained from the manufacturers.

58.33 - Centrifugation

Centrigual thickening of sludge is a process which uses the force developed by fast rotation of a cylindrical drum or bowl to separate the sludge solids and liquid. In the basic process, when a sludge slurry is introduced to the centrifuge, it is forced against the bowl's interior walls, forming a thin slurry layer or "pool." Density differences cause the sludge solids and the liquid to separate into two distinct layers. The sludge solids "cake" and the liquid "centrate" are then drawn from the unit separately and discharged. The three types of centrifuges - basket, disc-nozzle, and solid bowl - all operate on the basic principles described above. They are differentiated by the method of sludge feed, applied centrifugal force, method of solids and liquid discharge, and, to some extent, performance.

Additional information on design criteria can be obtained from manufacturers.

58.4 - Stabilization

Th principal purposes of stabilization are to make the treated sludge less odorous and putrescible, and to reduce the pathogenic organism content. Some procedures used to accomplish this objective can also result in other basic changes in the sludge. The selection of a certain method hinges primarily on the final disposal procedure planned for the sludge. If the sludge is to be dewatered and incinerated frequently no stabilization procedure is employed. Most stabilization methods, particularly anaerobic and aerobic digestion, result in a substantial decrease in the amount of suspended sludge solids. Hence, the corollary function of reduction is included in the description of the processes.

Both anaerobic and aerobic digestion are currently increasing inpopularity. The former is receiving revived attention because of the potential benefits of methane production, the energy shortage, increasing realization that many of the previous problems experienced were due to other wastewater process considerations, and the emphasis on final disposal on land. Interest in aerobic digestion of excess activated sludge is growing because it has the potential for providing a good quality liquid process stream and can produce exothermic reaction conditions. Composting is being practiced in several United States cities an is being actively investigated for others. A major impetus for processes such as anaerobic an aerobic digestion, lime treatment, and composting is the growing emphasis on utilization of sludge rather than mere disposal. Chlorine oxidation is of limited use for special situations or where septic tank wastes are involved. Irradiation and pasturization are also used but the present operational experience is not sufficient to consider these processes anything other than experimental. Heat treatment (pasturization) has been installed in several new United States plants to improve sludge conditioning and dewatering economics.

58.41 - Anaerobic Digestion

Digestion is a complex biochemical process in which several groups of anaerobic and facultative organisms simultaneously assimilate and break down

organic matter. For purposes of simplification, it is a two-phase process and can be described as follows:

1. In the first phase facultative, acid-forming organisms convert the complex organic substrate to volatile organic acids. Acetic, propionic, butyric, and other organic acids are formed. In this phase little change occurs in the total amount of organic material in the system, although some lowering of pH results. Alkaline buffering materials are also produced.

2. The second phase involves conversion of the volatile organic acids to primarily methane and carbon dioxide.

This anaerobic process is essentially controlled by the methane-producing bacteria. These bacteria grow at a relatively low rate and have generation times which range from slightly less than 2 days to about 22 days. Methane formers are very sensitive to pH, substrate composition, and temperature. If the pH drops below 6.0, methane formation ceases, and there is no decrease in organic content of the sludge. The methane bacteria are highly active in the mesophilic and thermophilic ranges. The mesophilic range is between 80 F, while the thermophilic range is between 113 F and 149 F. Essentially all digesters in the United States operate within the mesophilic temperature range. Heat input and mixers are required to operate within the thermophilic range. The thermophilic range is generally not used in smaller systems because of the additional equipment and maintenance required in spite of the fact that less digestion capacity would be required and the sludge produced would dewater better.

58.41a - Types of Anaerobic Digestion Systems

The standard and high rate systems are the two main digestion processes employed with the former being the most common in smaller systems. Schematics of the processes, as well as their operating criteria, are given in exhibit 1.

In practice, four types of systems have evolved from the two basic digestion modes. They are:

1. Standard Rate Digestion - One Stage.

2. High Rate Digestion - One Stage.

3. Two-Stage Disgestion.

4. Anaerobic Contact Process.

In the standard rate, one-stage digestion process as shown in exhibit 1(A), fresh sludge is usually added to the system two or three times daily. As decomposition proceeds, three distinct zones develop. A scum layer is formed at the top of the digester, and beneath it are supernatant and sludge zones. The sludge zone has an actively decomposing upper layer and a relatively stablized bottom layer. The stablized sludge accumulates at the base of the digester. Supernatant is usually returned to the influent of the treatment plant, although this practice can create problems and reduce overall treatment plant efficiency even is smaller plants.

The high rate, one-stage system (exhibit 1 (B)) requires a separate post-digestion thickening process if dewatering is practiced. This type system is increasingly being used in plants featuring anaerobic digestion because of the beneficial aspects of mixing, improved process control, and the lack of in tank settling problems.

Two stage digestion and the anaerobic contact process along with design criteria and performance data, are discussed in EPA's "Process Design Manual For Sludge Treatment and Disposal."

58.42 - Aerobic Digestion

Aerobic digestion describes the separate aeration of waste primary sludge, waste biological sludge, or a combination of waste primary and biological sludges in an open tank. It is usually used to stabilize excess activated sludges or the excess sludges from small plants which do not have separate clarification. The process involves the direct oxidation of any biodegradable matter by the biologically active mass of organisms and oxidation of microbial cellular material.

Endogenous respiration is normally the predominant reaction occuring in aerobic digestion. Stabilization is not complete until there has been an extended period of primarily endogenous respiration (15 to 20 days). Major objectives of aerobic digestion include odor reduction, reduction of biodegradable solids, and improved sludge dewaterability. Process advantages often cited for this process over other stabilization techniques are that it:

Is relatively simple to operate.

Requires a small capital expenditure compared to anaerobic digestion.

Does not generate significant odors.

Reduces the number of pathogenic organisms to a low level.

Produces a supernatant that, if clarified, is low in BOD, solids, and total P.

Reduces sludge's respiration rate.

The process is not without disadvantages. These may include high operating costs and unclear design parameters at present. Aerobically stabilized sludge generally has poor dewatering characteristics on vacuum filters. Ordinarily, this sludge is dewatered on sandbeds or applied in liquid form to cropland.

Process design and performance data are presented in EPA and manufacturers literature.

58.43 - Composting

Composting is genrally used to reduce the volume and moisture content of dewatered sludges. A bulking agent is mixed with the sludge to ensure voids and enhance air circulation. In the event that unstabilized sludges are composted, the bulking agent may have to be increased in quantity to compensate for the additional moisture content. Composting requires a

moisture content of 45-50 percent; therefore, it is more appropriate to consider this a volume reduction process as well as a stabilization process. A more thorough discussion of composting is presented in the reduction section, chapter 58.7.

58.44 - Lime Stabilization

The addition of lime, in sufficient quantities to maintain a high pH between 11.0 and 11.5, stabilizes sludge and destroys pathogenic bacteria. Lime stabilized sludges dewater well on sandbeds without odor problems. Sludge filterability can be improved with the use of lime; however, caution is required when sludge cake disposal to land is practiced. Disposal in thick layers could create a situation where the pH could fall to near 7 prior to the sludge drying out, causing regrowth of organisms and resulting in noxious conditions. Essentially, no organic destruction occurs with lime treatment. The key factor in assuring a proper stabilization process is the maintenance of a pH of around 11.0. In general, it has been determined that a pH of 11.0 can be maintained if the lime dosage is sufficient to raise the initial pH to 12.0 or greater for 30 minutes. The lime dose required to accomplish this may be estimated from the following tabulation.

LIME DOSE REQUIRED TO KEEP SLUDGE
pH 11.0 FOR AT LEAST 14 DAYS

TYPE	DOSE (1 b Ca(OH)2/ton sludge solids)
Primary sludge	200- 300
Septic tank sludge	200- 600
Biological sludge	600-1,000
Al sludge (secondary precipitation)	800-1,200
Al sludge (secondary precipitation) + Primary sludge (SSA1:SSPrim=1:1)	500- 800
Fe sludge (secondary precipitation)	700-1,200

58.45 - Chlorine Oxidation

This process is patented under the name Purifax. The Purifax process oxidizes sludge with heavy doses of chlorine (about 2,000 mg/1). Following treatment, the sludge dewaters well on sandbeds and it is stable. Purifaxed sludges may require chemical conditioning prior to dewatering on vacuum filters, since the sludge after treatment has a low pH (about 2). Supernatants an filtrates from the process contain high concentrations of chloramines. The process is costly to operate, primarily due to the cost of chlorine, although sludge disposal can also create problems due to the quantity and its very acid nature. Additional information can be obtained from the manufacturer.

58.46 - Irradiation

The major types of radiation are electromagnetic, acoustic, an particle. Gamma rays are emitted from radioisotopes, such as cobolt 60. Because of their penetration power, gamma rays have been used to disinfect both water

and wastewater. Although irradiation has also been shown to be effective in improving sludge filterability, it is not considered economically competitive at this time.

58.47 - Pasteurization

Heat treatment is a well known method of destroying pathogenic organisms and has been applied successfully for disinfecting sludge. Pasteurization implies heating to a specific temperature for a time period that will destroy undesirable organisms in sludge. It has recently been concluded that pasteurization at 70 C for 60 minutes is effective for destroying pathogens in digested sludge. A 75 C temperature will reduce coliform indicators below 1,000 per 100 m1 as well as destroying pathogens. This procedure is currently about the same cost as chlorine oxidation.