Forest Service Handbook
National Headquarters (WO)
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Duration: This amendment is effective until superseded or removed.

Superseded Directive: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:

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54.3 - Biochemical Aspects: Managing Dissolved Solids

A large portion of the BOD found in raw domestic wastewater is dissolved and cannot be removed in the pretreatment process through physical or mechanical means. When the wastes arrive at the plant in a septic condition, the facultative and anaerobic bacteria have begun utilizing the available oxygen, nitrates and sulfates, in the wastewater as their energy source.

The pretreatment process may be employed at the headworks of the treatment plant, or within the collection system itself, in order to mitigate any adverse impacts of septic wastes on the treatment process.

Methods commonly employed for this purpose follow.

54.31 - H2S and Odor Control

Fresh domestic sewage has only a slightly musty odor, and as long as aerobic conditions are maintained odors are minimal. Under anaerobic conditions, biological activity with sulfates produces hydrogen sulfide, which is one of the most common toxic by-products of septic domestic raw wastewater. Hydrogen sulfide, with its characteristic rotten egg odor, is not only extremely toxic to humans, but is a highly flammable gas. These odors should be controlled upstream of the plant through the use of aeration or chemical treatment.

54.31a - Prechlorination

Chlorination is probably the most widely used of the chemical treatment methods available to control odors because of its effectiveness and because it is usually available at the treatment plant. The application of chlorine acts on the odor producers by reacting chemically with odorous sulfur compounds, oxidizing them to innocuous forms and by retarding biological action. The prime consideration here is that the chlorine dosage should not produce a high residual chlorine level which may in turn be detrimental to secondary biological units.

54.31b - Preaeration

The prevention of odor problems through preaeration is effective with relatively short aertion periods, in the order of 15 minutes. Additional improvements to the treatability of raw wastewater by longer aeration periods include the benefits of grease separation and improve flocculation of solids. The main considertions in the design of preaeration facilities are air application rate and retention time. Detailed design data is available in references.

54.31c - Hydrogen Peroxide

Hydrogen peroxide is used to control hydrogen sulfide in wastewater. Hydrogen peroxide reacts with hydrogen sulfide to form water and sulfur. Theoretically, this reaction requires a 1:1 ratio; however, in practice a higher ratio is used. The result is a contribution of dissolved oxygen which inhibits the regeneration of hydrogen sulfide.

54.32 - Heavy Metals Control

Forest Service wastewater plants will normally not be involved with the treatment of wastewaters that contain a high concentration of heavy metals. However, the type and source and control of these wastes is briefly discussed.

54.32a - Types and Sources

Most wastewaters that contain heavy metals are associated with discharges from industrial processes or manufacturing plants. Metal finishing wastes contain oil, cyanide, chromium, and other toxic metal ions. Textile wastes have relatively high BOD and total solids concen- trations. Food processing wastes have a high grease content and may also contain large amounts of nitrogen and phosphorus. Many manufacturing wastes contain refractory compounds such as dissolved salts. The strengths and toxicity of these wastes varies greatly with the process or product involved.

54.32b - Effects on Treatment Processes

Most industrial wastewaters containing heavy metals or other toxic materials or having other high strength substances will have an adverse effect on biological treatment processes. The degree of problem can range from total destruction of the biological organisms due to toxic metal ions to a temporary upset of the plant efficiency because of unequalized flows. BOD concentrations can be much greater than those for domestic wastes. Total solids are greater and vary in character from colloidal and dissolved organics, to predominantly inorganic salts. The suspended solids concentration relative to BOD must be considered when using conventional sedimentation and secondary biological treatment. The high strength, settleability, nutrient content, and toxicity of these wastes must be controlled to alleviate the impact on the treatment processes and to provide an acceptable final effluent.

54.32c - Control

The majority of industrial type wastes are more amenable to biological treatment after dilution, generally with domestic wastewater flows. However, regulations now require pretreatment at the source for wastes having strengths or characteristics significantly different from sanitary wastewater.

The method or type of pretreatment includes waste strength reduction, flow equalization, by-product recovery, inplant wastewater reuse, and segregation of waste streams for individual pretreatment or controlled mixing and separate disposal. Pretreatment of these wastes prior to discharge into conventional biological treatment systems will reduce or eliminate the adverse effects experienced in the past.

55 - Primary Treatment

This term refers to a process (generally sedimentation) which removes 25 to 35 percent of the 5-day BOD and about 60 percent of the suspended solids from raw wastewaters. The heavy solids in the wastewater settle to the bottom of a tank from which they are removed for further treatment. The liquid discharged from the primary clarifier is called primary effluent.

Clarification of wastewater is the process of removing materials in the water such as turbidity, sediment, and floatables. Prior to clarification in the "Primary Treatment" schematic, municipal size plants will have screening, comminuting, degritting, and scum and grease removal devices. These devices are referred to as "pretreatment" devices and are discussed in section 54.2.

55.1 - Physical Treatment Processes

55.11 - Sedimentation

Sedimentation is a basic "unit operation" using gravity to settle solid particles through a liquid, usually water. If wastewater is slowed or stopped, the suspended solid particles with a specific gravity heavier than the liquid will settle out. The maximum removal of suspended solids is accomplished when the settled matter is removed often. Standard reference texts are available for design application.

55.12 - Flotation

Flotation refers to a "unit operation" in which buoyancy is used to separate solid or liquid particles from the parent suspension. If small air bubbles are allowed to rise through wastewater, they will carry light suspended solids to the surface. These solids will join others and form a blanket that can be removed by mechanical means.

55.13 - Clarification

The unit operations of sedimentation and flotation are used in the clarification process to remove the mass of solids referred to as "raw sludge." The sludge is gray, generally has an objectionable odor, is stickly, and does not give up its water readily. It can be air dried successfully only in thin layers, with an accompanying foul odor. Primary sludge, when removed from the clarifier, contains 2 to 8 percent solids with an average of about 5 percent. Properly designed sedimentation tanks remove from 40 to 70 percent of the suspended solids and 25 to 35 percent of the BOD5.

Most clarifiers are sized by surface overflow rate and retention time. Typical overflow rates range from 200 to 1800 gpd/square foot. Detention times used are generally 1 to 4 hours. The shape of clarification tanks may be circular, square, or rectangular. Sludge collector mechanisms move on the bottom of the tanks and force the settled solids along to a removal point.

When similar collector mechanisms are used for the primary purpose of increasing the settled solids concentration, the equipment is then referred to as a sludge thickener (see 58.3).

55.2 - Primary Treatment/Disposal: Septic Tank - Soil Absorption Systems

A common, and quite often satisfactory, method of waste disposal for individual homes and small institutional facilities, including Forest Service installation, is the septic tank and subsurface soil absorption system. Although such systems are often used only where adequate public sewer systems are lacking, if properly designed, constructed, and operated, septic tank

systems can be a very effective and economical disposal method. However, as with all engineered works, the constraints limitations of these systems must be known and observed in order to produce a satisfactory result. The fact that so many septic tank systems do fail or operate poorly is mute testimony to the inadequacy of design, construction or operation/maintenance.

55.21 - Septic Tank

The septic tank is an important component of the septic tank - soil absorption system. Its primary purpose is to condition the sewage so that there will be less clogging of the disposal area, thereby maintaining the absorption capacity of the soil. Three functions of the septic tank include: (1) removal of solids by particulate sedimentation and flotation of scum and grease; (2) a moderate degree of suspended solids liquefaction by means of anaerobic decomposition; and (3) storage of inert residual settled solids (sludge) and floating matter such as grease and scum.

55.21a - Common Design Practice and Regulatory Constraints

Minimum septic tank capacity, dimensions and materials of construction, etc., may be found in the Manual of Septic Tank Practice, Public Health Service Publication No. 526, (PHS-MSTP) revised 1967, The Uniform Plumbing Code (UPC), and State regulations. The MSTP is currently being revised.

Minimum capacities for septic tanks normally include volume for garbage grinder and automatic clothes washer use as well as sludge storage. However, it is recommended that garbage grinders not be used in septic tank - soil absorption systems.

The PHS-MSTP design basis is daily sewage flow in gallons per day; but the UPC basis is either number of bedrooms or maximum permissible number of fixture units where the facility does not include bedrooms.

Most State health departments have, in the past, adopted the PHS recommended septic tank capacities and utilized them for their own guidelines, regulations, etc. However, not all States employ the exact same guidelines. When preparing a septic tank system design, capacities required by the State health agency may not necessarily be the same as the PHS-MSTP. Capacities recommended by the State should be used when larger than those of MSTP or UPC; otherwise, the latter shall be used.

A two compartment tank with the first compartment equal to 2/3 the total volume provides better solids removal than a single compartment tank. Whenever a first compartment exceeds 12 feet in length, an additional manhole shall be provided over the baffle wall.

The location of septic tanks with respect to water courses, wells, buildings or other structures is generally regulated by State or county health agencies. Always check with the local health or water quality control agency prior to the design of a septic tank system. Forest Service facilities must comply with required setback distances required by State or local regulatory agencies.

55.21b - Septic Tank Wastewater Characteristics

The performance of septic tanks and the waste strength parameters such as BOD, COD, etc., of septic tank effluents (not the pumped septage, but the liquid effluent) are not often available in textbooks or design manuals primarily because this effluent is merely "disposed" of in the soil absorption system and hence no specific knowledge of it is required. However, stricter ground water quality monitoring requirements, now often imposed on large subsurface disposal systems, and the use of septic tanks as settling and surge tanks in smaller diameter pressure sewer systems require a working knowledge of the effluent characteristics from septic tanks.

Data on individual home wastewater and septic tank effluent wastewater characteristics from recent studies are summarized in the Table 1 below:

Table 1: Individual Home Wastewater Characteristics

	BOD5 (mg/1)	COD (mg/1)	S.S. (mg/1)	Total Nitrogen (mg/1)	Total Phosphorus (mg/1)
Individual home waste-water characteristics (avg. values)	280	840	310	70	17
Septic tank effluent from individual home systems (avg. values)	160	360	55	55	15
Average removal effi-ciency of septic tank	44%	57%	83%	21%	14%

As can be seen, the septic tank is moderately efficient at removing BOD5 and COD. It is efficient at removing suspended solids.

55.21c - Critical Operation and Maintenance Guidelines for Septic Tank Installations

Septic tanks must be pumped before the depth of sludge or scum buildup reaches a point where either may be washed out in the effluent and into the soil absorption field. Once this happens, an absorption system can fail quickly.

To avoid such a possibility, tanks must be inspected at least once every year. The inspection is made to determine the depth of sludge in the bottom of the tank and the thickness of the scum layer. The tank must be pumped if either; (a) the bottom of the scum mat is within approximately 3 inches of the bottom of the outlet pipe, or (b) sludge comes within the limit specified in Table 1.

Table 1: Allowable Sludge Accumulation

Liquid capacity of tank gallons	LIQUID DEPTH 2-1/2 feet	3 feet	4 feet	5 feet
	distance from bottom of outlet device to top of sludge, inches			
750	5 (43)	6 (43)	10 (39)	13 (38)
900	4 (47)	4 (49)	7 (45)	10 (43)
1000	4 (47)	4 (49)	6 (48)	8 (47)

Figures in parenthesis are percent of total liquid capacity representing the portion of capacity available for sludge storage. Allowable sludge accumulation for tanks larger than 1,000 gallons may be estimated at 48 percent of total liquid capacity. Although there are wide differences in the rate at which the sludge or scum accumulates from one tank to another, Table 2 estimates the theoretical interval between required tank pumpouts for several tank sizes and population served based on allowable sludge storage indicated in Table 1.

Table 2: Theoretical Time Interval Between Tank Pumpout

	750 Gal. Tank (308 Gal. Sludge Storage)		900 Gal. Tank (415 Gal. Sludge Storage)		1000 Gal. Tank (475 Gal. Sludge Stor.)	
No. of persons served by Tank	Years Accum. w/Biodegradation	Years Accum. without	Years Accum. w/Biodegradation	Years Accum. without	Years Accum. w/Biodegradation	Years Accum. without
2	6.7 yrs.	1.8	9 yrs.	2.5	10.3 yrs.	2.8
3	4.5	1.2	6	1.7	6.9	1.9
4	3.3	.9	4.5	1.2	5.2	1.4
5	2.7	.7	3.6	1.0	4.1	1.2
6	2.2	.6	3	.8	3.4	1.0
7	1.9	.5	2.6	.7	3.0	.8

Table 2 was prepared on the basis of average conditions including 45 gpcd sewage flow, 310 mg/1 TSS into tank, and 55 mg/1 TSS out of tank with 79 percent of S.S., being volatile, and digested septic tank sludge of 10 percent solids and 1.04 sp. gr. Biodegradation presumes 60 percent reduction

of volatile suspended solids. No biodegration assumes 0 percent reduction of volatile S.S. and a "primary" undigested sludge with 5 percent solids and 1.02 sp. gr. The case of no biodegration is an extreme care which is very unlikely to happen except in unusual conditions where anaerobic digestion is poisoned by heavy metal (lead, zinc) accumulation in the sludge in excess of 150 to 200 mg/1. Most soluble bactericidic agents which could inadvertently enter the septic tank would tend to be washed out and its effect would only be temporary.

Septic tanks which receive recreational trailer waste could conceivably be subjected to high concentration of formaldehyde. Formaldehyde is a powerful bactericide which may affect the rate of anaerobic digestion in the septic tank, resulting in the need for more frequent pumping.

Table 2 should only be used as a rough guide to pumpout frequency since it is based on a combination of many variables, each of which may deviate significantly from average values.

While inspection to determine the need for pumping acccumulated sludge is necessary, measurements to determine scum layer thickness are equally important. Characteristics of the raw sewage can greatly affect the rate of scum buildup. Inspections may be necessary more frequently than the once per year recommended minimum.

Scum can be easily measured with a pole to which a weighed flap has been hinged or with any device that can be used to fuel out the bottom of the scum layer. The pole is forced through the scum mat, the hinged flap falls into a horizontal position, and the pole is raised until resistance from the bottom of the scum is felt. With the same tool, the distance to the bottom of the outlet device can be established. The difference in elevations is then determined, and as previously noted, if the bottom of the scum layer is within approximately 3 inches of the bottom of the outlet device, the septic tank must be pumped.

55.22 - Disposal Area

Although the proper design, construction, an maintenance of both the septic tank and the wastewater absorption system are equally important, the more critical factors are associated with the absorption system because of the greater variability and lack of definitive knowledge in this area. Proper performance of surface or subsurface wastewater disposal by soil absorption depends upon the ability of the soil to absorb and treat the wastewater. Failure occurs if either of these functions is not performed.

55.22a - Soil Characteristics in Relation to Absorption Disposal

Soil characteristics which bear upon its absorption capacity for wastewater include porosity, permeability, moisture potential, hydraulic conductivity, pore clogging phenomena, and unsaturated flow.

1. Soil Porosity and Permeability. Soil permeability or capability to conduct water is not determined by the soil porosity but rather the size, continuity, and tortuosity of the pores. These pathways through which the water moves are constantly being altered by wetting, drying, freezing, biological activity, and root growth.

2. Moisture Potential. Under natural drained conditions, some pores are filled with water. The distribution of this water depends upon the characteristics of the pores while its movement is determined by the relative energy status of the water. The energy status is referred to as the moisture potential. The moisture potential has four components of which the two most important are the gravitational and matrix potential. The gravitational potential results from gravitational attraction toward the center of the earth. The matrix potential is produced by the affinity of water to the soil particle surfaces. The pores and surfaces of soil particles hold water due to forces of absorption and surface tension. The surface tension forces effect the phenomenon of capillary water movement in soil, while the absorptive forces create increasing soil moisture tension or suction forces during drying of soil.

3. Hydraulic Conductivity. Water will flow from a point where it has a higher potential to a point of lower potential. The gravitational potential acts to move water downward while the matrix potential attracts water in all directions, but only if the soil is not saturated. The rate of flow increases as the difference of potential gradient between points increases. The ratio of the flow rate to the potential gradient is referred to as the hydraulic conductivity or K defined by Darcy's Law.

This parameter (K) accounts for all the factors affecting flow within the soil including tortuosity and size of the pores. Thus, the measured K values for different soils vary widely due to differences in pore size distributions and pore continuity.

The reduction of K upon increasing soil moisture tension is characteristic for a given soil texture and structure. Coarse soils with predominantly large pores have relatively high saturated hydraulic conductivities (Ksat), but K drops rapidly with increasing soil moisture tension. Fine soils with predominatly small pores have relatively low Ksat, but hydraulic conductivity decreases more slowly upon increasing tension. Hydraulic conductivity or K curves, determined in situ show such patterns for natural soil (see exhibit 1).

Exhibit 1: Hydraulic Conductivity as a function of soil moisture tension measured in situ.

SEE PAPER COPY FOR EXHIBIT 1

4. The Process of Pore Clogging. When liquid wastes are applied to the soil, a clogging zone often develops at the infiltrative surface. This restricts the rate of infiltration, preventing saturation of the underlying soil even though liquid is ponded above. The soil is then able to conduct liquid only if the water is able to penetrate the clogged zone under the forces of hydrostatic pressure and capillary pull.

Several phenomena contribute to the development of a clogging zone at the infiltrative surface of soil absorption systems. These include:

(a) Compaction, puddling and smearing of the soil during construction.

(b) Puddling caused by the constant soaking of the soil during operation.

(c) Blockage of soil pores by solids filtered from the waste effluent.

(d) Accumulation of biomass from growth of microorganisms.

(e) Deterioriation of soil structure caused by exchange of ions on clay particles.

(f) Precipitation of insoluble metal sulfides under anaerobic conditions.

(g) Execretion of slimy polysaccharide gums by some soil bacteria.

Studies by several investigators indicate that the physical and biological mechanisms are the primary causes of soil clogging in an absorption field which have not already been smeared and compacted during construction. In these instances, clogging seems to develop in three stages: (1) slow initial clogging, (2) rapid increase of resistance leading to permanent ponding, and (3) a final leveling off toward equilibrium.

The process can be reversed to restore much of the original infiltrative capacity if the ponded surface is allowed to drain and rest to permit aerobic biological decomposition and the drying and cracking of the clogging materials. Aerobic biological decomposition can be augmented or supplanted by chemical oxidative proceses, such as by the addition of certain ozidizing chemicals to a clogged leachfield.

This description of soil clogging assumes that the native soil structure is left relatively intact at the infiltrative surface during construction of the system. However, many systems fail, usually within a year or two, because of poor construction techniques.

Rapid absorption of waste effluent by soil requires maintaining open pores at the infiltrative surface, but often the pores are sealed during construction by compacting, smearing, or puddling. The following construction techniques are recommended to minimize soil clogging.

Work in clay soils only when moisture content is low.

Keep equipment off the bottom of a trench.

Construct shallow systems to place the infiltrative surface in more permeable horizons. This is particularly beneficial in clayey soils as they are generally wetter for longer periods of time, especially at greater depths.

Remove smeared or compacted surfaces. Compaction may extend as deep as 8 inches in clays. If so, a fresh infiltration surface needs to be exposed.

Schedule work only when the infiltration surface can be covered in 1 day because wind-blown silt or raindrop impact can clog the soil.

Long liquid travel times are desirable to adequately treat the wastewater. The design of absorption systems may be critical to achieve this in some soils. Travel times are sufficiently long under all moisture tensions to

affect adequate treatment in clay, but are too short in sand and sandy loams when the soil is near saturation. Once a clogging zone has developed in such permeable soils, moisture tensions reach a level where sufficiently long travel times result. However, when an absorption system constructed in a high porous or dry structured soil is first put into service without a developed clogged zone, treatment of the effluent will be very low.

55.22b - Wastewater Treatment Capabilities of Soils

The principal goal in soil-waste disposal is the treatment of the waste before it reaches ground water. Organic matter, chemicals and pathogenic organisms and viruses that are not removed prior to application to the soil must be removed or transformed by the soil material. Numerous studies have shown that under the proper conditions the soil is an extremely efficient medium for this purpose.

Chemical transformations and removals by soils include forms of nitrogen and phosphorous. Nitrogen in septic tank effluent is about 80% ammonium and 20% organic nitrogen, but much of it is converted biologically to nitrate as it moves through the aerobic unsaturated soil immediately below the clogging zone in the seepage field. If anaerobic conditions prevail in the subsoil, nitrification will not occur and the nitrogen then remains in the form of ammonium. Ammonium is readily absorbed by soil materials of high clay content and hence migrates much more slowly.

Phosphorous is of environmental concern if allowed to reach surface waters because it can accelerate eutrophication as it is an essential nutrient of algae and acquatic weeds. However, phosphorous enrichment of groundwater seldom occurs below septic tank systems because phosphorous is fixed in soil by sorption reactions or as phosphate precipitates of calcium, aluminum or iron. Calcium is usually found in the wastewater and aluminum and iron are abundant in most soils. Phosphorous leakage to the groundwater may occur, however, where high water tables exist, very coarse sand and gravel occur, or where the seepage bed has been loaded heavily for a long period of time. Phosphorous can move downward 20 to 40 inches per year through coarse silica sand, but movement in loams, silt loams and clays is less than 2 to 4 inches per year.

55.22c - Soil Permeability and Design Criteria for Subsurface Soil Absorption Disposal Systems

Criteria for site selection and design of soil absorption systems vary from folk knowledge and experience to various empirical methods of site testing and design often codified into rules. The U.S. Public Health Service has developed a general reference manual (Manual of Septic Tank Practice) which has provided guidelines for many State, Regional and local manuals or codes of practice.

Several factors are usually considered in the selection of a site and design of a soil absorption system. The ability of the soil to absorb liquid, usually estimated by the percolation test, is a common requirement. Other factors include slope, depth to groundwater, nature and depth to bedrock, likelihood of seasonal flooding and distance to well or surface water. These traditional factors have several limitations and vary widely between codes. If a site satisfies all requirements for key factors, depth to bedrock, groundwater, slope flood plain, then the soil type and infiltrative capacity should be determined.

1. Estimation of High Groundwater. To ensure adequate treatment of the wastewater before it reaches ground water, a minimum of 3 feet of unsaturated soil is necessary below the infiltrative surface. The MSTP recommends the maximum seasonal elevation of the ground water should be at least 4 feet below the infiltrative surface. If saturated soils occur within this distance(s), transmission of harmful pollutants to the ground water may result.

Determining if saturated conditions occur with the minimum allowable distance is often difficult. Water table levels fluctuate with changing weather conditions. Ideally, the highest ground water level should be recorded, but this may not be practical. Typically, the water table is low during the summer and rises in the spring or fall. Moreover, observations made in relatively dry years are not representative. Other methods must be used to determine the high water elevation.

Soil mottling can indicate seasonally high water levels. Mottles are spots of contrasting colors found in soils subject to periodic saturation.

The spots are usually bright yellow-orange-red, have a gray-brown matrix, and are described according to color, frequency, size, and prominence. Well-drained soils are usually brown because of finely divided insoluble iron and manganese oxide particles throughout the horizon. Under reducing conditions often produced by prolonged saturation, iron and manganese are mobilized until reoxidized when the soil drains. Repeated wetting and drying cycles quickly produce local concentrations of these oxides on pore surfaces, forming red mottles. Soil from which much of the iron and manganese has been completely reduced turns from brown to gray, a process referred to as gleying. The upper limit of the mottled soil, therefore, is often a good estimate of the high ground water level. This condition may also be the result of a periodic perched water table. The latter possibility can be confirmed by a lack of mottles in lower horizons.

2. Estimation of Soil Permeability.

a. The Percolation Test. The percolation test is based on the assumption that the ability of a soil to absorb sewage effluents over a prolonged period may be predicted from its initial availability to absorb clear water. The results of this test are highly variable, however, and its use for system sizing relies on an empirical relationship between the measured percolation rate and the actual loading rate. Tests run in the same soil can vary by as much as 50 percent; thus, the reliability of the procedure is questionable.

b. The Crust Test. The soil below most operating absorption systems is unsaturated because of the clogging mat that develops at the infiltative surface. Therefore, to properly size an absorption system, the unsaturated K characteristics of the soil must be known. Because the standard percolation test does not provide this type of data, the crust test was developed.

The test is a permeability test which attempts to take into account those inherent soil characteristics that reflect soil absorption field performance after biological clogging or ponding has occured. Basically, hydraulic conductivity is measured in situ under various moisture potential conditions,

thus defining a conductivity curve versus soil moisture for a given type soil.

3. Design Criteria for Absorption Areas. Presently, there are two widely accepted sources of design criteria for septic tank-absorption systems: The PHS Manual of Septic Tank Practices (MSTP) and the Uniform Plumbing Code (UPC). Both of these sources draw the basis of their design criteria from the same research; but because of slight variations in application, the results are different. The PHS-MSTP establishes two relationships between measured percolation rates and required absorption area; one is for individual residences and the other for public systems. On the other hand, the UPC utilized rated absorption capacities of 5 typical soils related to required absorption area per 100 gallons of septic tank capacity.

As previously discussed, the percolation test is based on an empirical relationship between the measured percolation rate and the actual loading rate. The lack of repreducibility and reliability on tests run in the same soil, makes the effectiveness of this test questionable.

The crust test is performed in situ to avoid distrubing natural pores and to maintain continuity with the underlying soil. The test procedure results in a measured soil moisture tension and an equilibrium flow rate to locate one point on the K curve. Additonal tests run with crusts of various hydraulic resistances define the K curve (see 55.22a, exhibit 1).

This procedure offers a direct measurement of K, but it is time consuming, requires a skilled operator, and cannot be run economically at each site. However, because K depends on the pores in the system, the conductivity of a soil at various sites can be defined within statistical limits. Also, variability curves of soils in the same textural groups have similar K curves. Therefore, by defining families of K curves for groups of soils, the K characteristics of a particular soil or site can be predicted.

To make these curves useful in designing soil absorption fields for septic tank systems, soil moisture tensions were measured under the clogging zones of several operating fields. This information provided a design point on the curve for proper field sizing. A compilation of this date for various soil types is summarized in Table 1 which represents the best estimates to date.

Table 1: Recommended maximum loading rates 1/

Estimated percolation rate (min/inch)	Soil texture	Maximum loads 2/ ing rate gpd/ft2	Recommended operating Conditions
0-10	sand	1.20	4 doses/day uniform distri- bution trenches or beds
10-30	sandy loams, loams	0.60	1 dose/day uniform distribu- tion, trenches preferred.
30-45	some porous silt loams, & silty clay loams 3/	0.50	1 dose/day uniform distri- bution shallow trenches only 4/
45-90	clays, some compact silt loams & silty clays 3/	0.24	dosing and uniform distribution shallow trenches only 4/

1/ Septic tank effluent for different soil types based on the results of crust tests and observation of soil moisture potential under clogged field.

2/ Bottom area only.

3/ Not applicable in the presence of expansive clays.

4/ Use shallow trenches if necessary to maintain at least 3 feet of unsaturated soil between bottom of trench and saturated soil level during periods of highest groundwater table.

4. Sewage Application Rates for Forest Service Facilities. Since the reliability of the percolation test results are questionable, but because the crust test procedure cannot be run economically at every site, the following procedures are recommended for determining the size of absorption trench systems for Forest Service facilities.

a. Use the standard PHS-MSTP percolation test, employing a minimum of eight test holes dispersed throughout the area to determine the percolation rate.

b. Make an accurate determination of maximum daily sewage volume generated at the facility.

c. Use the maximum sewage application rates based on the type of soil test used to calculate the required absorption trench area.

d. Check to see that the computed absorption trench area is equal to or greater than area requirements under State and local codes.

5. Other Design Factors. There are also other important design factors to consider besides the sewage application rates. The absorption field should receive uniform distribution of sewage throughout the length of the absorption trench, preferably in the form of periodic dosages to allow for rest periods between applications. However, controlled dosing is not always required for proper system performance. It may be necessary to control dosing, if an area producing substantial flows is connected to a single absorption field, in order to maintain aerobic conditions. Single residence system (or similar small systems) normally do not need special provisions to achieve this objective. Water consumption patterns in small systems will automatically permit the maintenance of aerobic conditions in the trench about 50 percent of the time. Experience has shown that small systems will perform satisfactorily for many years without controlled dosing if the absorption area is sized in accordance with proper criteria. The use of siphons or pumping systems must be carefully investigated to ascertain that they are necessary for proper system operation.

Two distinct factors enter into the design criteria for uniform distribution and dosage. One factor is the storage volume of the dosing siphon tank (or pump wet well capacity) and the other factor is the proper length, size and perforations in the absorption trench piping.

6. Dosing Volume. The dosing volume must be equal to anywhere from 1 day's sewage flow to 1/4 of a day's sewage flow. In other words, for every 1,000 gallons per day of sewage flow, dosing tank volume should be 250 gals. to 1,000 gals. to allow for 1 to 4 doses per day. At the minimum, however, the dosing volume should allow for 20 percent saturation of the pore volume in the absorption trench. For example, a trench 2 feet wide, 1 foot deep (gravel below pipe) and 100 feet long will have a total gravel pack volume of 100x2x1=200 cubic feet below the pipe. If the gravel pack has a porosity of 0.20, the pore volume will be 0.2x200=40 ft.3=300 gallons. Thus, for the 100 foot long trench, the minimum dosing siphon tank volume should be 0.20x300=60 gallons. On the other hand, maximum dosing siphon tank volume should not exceed the total pore volume of the absorption trench gravel pack.

7. Absorption Trench Piping. In order to uniformly dose an absorption trench, absorption trench systems must be designed to distribute uniform flow to each branch and from each branch through all perforations (holes) in the branch piping. The pipe network should be designed such that most of the total energy required to deliver the waste to the trenches is lost across the perforations in the pipe. If this requirement is satisfied, the entire network will fill before much liquid is lost through the orifices nearest the discharge chamber (pump or siphon). Design variables include orifice

diameter, number of orifices, lateral diameter, manifold diameter an discharge head.

Guidelines for balancing these variables are as follows:

a. The diameter of orifices should be 1/4 inch to 3/4 inch.

b. The ratio of cross-sectional area of the laterals to the total area of the orifices served should be (2-4):1.

c. The ratio of the cross-sectional area of the manifold to the total cross-sectional area of the laterals served should be (1.5-3):1.

d. All pipe diameters should be no smaller than 1 inch diameter to prevent clogging by any solids in the effluent.

e. Perforations should not be spaced further than 24 inches on center.

f. Discharge velocity through the orifices should not exceed 7.5 fps.

g. Soil trench widths should not be wider than 4 feet to ensure the entire trench bottom area is utilized.

h. A pressure at the ends of laterals of 2 feet of water (0.866 psi) is desirable to assure adequate flow to the far end of the network.

By using these guidelines and applying an adequate discharge pressure, uniform distribution should be achieved.

55.22d - Alternate Absorption Systems

Certain site conditions may prohibit the use of subsurface absorption systems. Such sites may include one or more of the following conditions: (1) very slowly permeable soils with or without seasonally high water tables; (2) permeable soils with high water tables; (3) shallow permeable soils underlain by bedrock on steep slopes. Under these adverse site conditions, above ground disposal may be practical employing the mound or fill systems refined by Converse, Otis, Bouma, et al., of the University of Wisconsin at Madison. The predecesor to the mound system is the Nodak System named after its developers at North Dakota State University. Both the Nodak and the more recent mound system utilize the same basic principles which are: (1) elevation of the absorption trenches above natural soil in a permeable sand fill where the sewage may percolate through suitable filtering media before reaching ground water table or bedrock; (2) design of the basal area of the sand fill to maximize the spread of sewage effluent throughout the permeable fill so that as it reaches the less permeable subsoil it can be absorbed; and (3) the daily dosing of absorption area by a pressurized small diameter pipe system to achieve maximum uniform distribution of sewage effluent. Detailed design of mound systems is presented in publications authored by J. C. Converse, R. J. Otis, J. Bouma, et al. Available through the Small Scale Waste Management Project Publications Dept.; 1 Agriculture Hall; University of Wisconsin; Madison, Wisconsin, 53706.

55.22e - Maintenance and Restoration of Absorption Fields

Soil absorption fields often fail after several years of satisfactory service because the clogging zone develops to a point where insufficient amounts of effluent pass through it. Two methods have been used to rejuvenate failed systems.

One effective method is resting the system. Resting allows the absorption field to gradually drain, exposing the clogged infiltrative sere insufficient amounts of effluent pass through it. Two methods have been used to rejuvenate failed systems.

One effective method is resting the system. Resting allows the absorption field to gradually drain, exposing the clogged infiltrative surface to air. After several months, the clogging materials are broken down in physical and biochemical processes, restoring the infiltrative capacity of the field. A second field must be available to allow continued use of the disposal system while the failed field is rested.

The infiltrative surface can also be rejuvenated by adding oxidizing agents to the absorption field. Oxidation serves the same function as resting, but the clogging zone is destroyed in a day or two rather than several months. This method does not necessitate taking the clogged bed out of service. Laboratory and field tests have shown that chemical oxidation can restore the infiltrative surface to near its original permeability. THe preferred oxidant is hydrogen peroxide because it is effective at the natural pH of absorption fields, produces no noxious by-products, and is inexpensive.

Hydrogen peroxide (H2O2) treatment is most efficient in a preventative maintenance program. Smaller quantities are involved which makes it cheaper and safer to handle. Five gallons of 50 percent H2O2 may be adequate to reduce the clogging developing in a field. This is because the field is still permeable and the oxidant can reach the clogging zone more easily than it could in a failed field. H2O2 treatment should be performed when the system is not in use, or during periods of low flows. This will give the reagent time to work without being diluted with peak flow effluent and to allow aerobic conditions to become well established in the bed.