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Duration: This amendment is effective until superseded or removed.

Superseded Directive: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

56 - Secondary Treatment

Secondary treatment of wastewater reduces the concentrations of dissolved and colloidal organic matter through biological action. Reductions of 5 day BOD by 85percent and suspended solids by over 90 percent are generally possible with conventional secondary treatment processes.

There are inherent characteristics at Forest Service facilities which make secondary sewage treatment difficult. These are:

1. Relatively small populations served.

2. Variable hydraulic and organic loads.

3. Restricted areas for treatment facilities.

4. Unusually low temperatures.

5. Remote locations and part-time operation preclude operation and maintenance by highly skilled personnel.

These characteristics, often coupled with minimal operation and maintenance, frequently result in reduced performance of the secondary treatment process. Systems serving seasonal populations (summer campgrounds and winter sport areas) are faced with additional constraints. The treatment facility must be large enough to handle the expected maximum flow, yet still operate satisfactorily in periods of low flow. Plant design can compensate, to some degree, for all of these factors provided accurate hydraulic and biological loadings are known. Good operation and maintenance procedures are necessary to obtain designed effluent quality.

Because the design of secondary treatment facilities is a complex process, proposals shall be submitted to the Regional Office for design assistance, review and recommendations (FSM 7430 and 7440). Various State and local regulations also affect the design of wastewater treatment facilities.

Every secondary treatment facility will require daily attention by a trained operator, ranging from 1 to 2 hours per day on simple facilities to full-time with backup personnel on more complex facilities. The operator must be able to sample and test the wastewater; perform maintenance and make minor repairs on mechanical, hydraulic, and electrical systems; and make any necessary adjustments in the operational procedures. A trained operator can tell if the facility is functioning properly by observation and testing. The specific operating characteristics, including biological, mechanical, hydraulic, and electrical, must be detailed in an Operation and Maintenance Manual for each secondary treatment facility (see chapter 70).

Effluent discharge and sludge disposal options are very important considerations in selection of a suitable secondary treatment facility. Other sections of this chapter will discuss these items.

56.1 - Biological Processes

Waste stabilization is accomplished by an established mixed population of micro-organisms generally converting the organic matter in the waste to carbon dioxide and new bascterial cells. These processes are classified by the oxygen-dependence of micro-organisms in the wastewater. Aerobic, anaerobic, and facultative micro-organisms are responsible for the waste stabilization. Aerobic micro-organisms can exist only when there is a supply of free oxygen. Anaerobic micro-organisms can exist only in an environment that is void of free oxygen. Facultative micro-organisms have the ability to survive with or without free oxygen.

A great portion of the BOD-5 of influent wastewater is removed in a well operating biological treatment process. Any BOD-5 in the effluent is due primarily to the respiration of organisms carried into the effluent.

The most common problem associated with biological process treatment is that variable feeding of the micro-organisms adversely affects their number. Severe increase or decrease in loading can cause upset in the treatment process, thus affecting effluent quality.

56.11 - Activated Sludge

This process converts nonsettleable substances in finely divided, colloidal, and dissolved form into a biological floc, or activated sludge. The basic characteristic of activated sludge is that it disperses when agitated and flocculates when agitation ceases.

In the activated sludge process, incoming wastewater is mixed with the sludge returned to the aeration tank and this mixture is aerated sufficiently to mix the tank contents. The mixture of incoming wastewater and the activated sludge solids is commonly called the mixed liquor. Sludge must be returned from the final clarifier to maintain a sufficient concentration of activated sludge in the aeration tank to obtain the required degree of treatment in the time interval desired. Most of the settled sludge is returned from the clarifier to the aeration tank; however, a portion of the sludge is wasted. This waste sludge is a result of bacterial growth as well as the accumulation of non-biodegradable suspended solids which enter the system. Sludge should be wasted frequently and in small volumes to avoid large changes in the process operation.

Activated sludge treatment plants can be bought as a package plant or constructed on site. The essential components are an aeration tank with the necessary aeration equipment, a final clarifier or sedimentation basin, in which the biological solids can be separated from the liquid effluent, and the necessary pumps to recycle the concentrated solids to the aeration tank.

The function of the clarifier is to separate the activated sludge solids from the mixed liquor. This constitutes the final step in the production of a well clarified, stable effluent low in BOD and suspended solids and is a critical link in the operation of an activated

sludge treatment process. The presence of the large volume of flocculent solids in the mixed liquor requires that special consideration be given to the design of clarifiers. These solids tend to form a sludge blanket in the bottom of the tank and may fill the entire depth of the tank and overflow the weirs at peak flow rates if the return sludge pump capacity or the size of the clarifier is inadequate.

Basic parameters in the design of an activated sludge process are:

1. Influent waste quantity and characteristics.

2. BOD-5 removal rate.

3. Oxygen requirements and transfer rate.

4. Sludge production, separation and transfer rate.

5. Nutrient requirements.

The activated sludge process has been modified in several ways since the process was first applied to wastewater treatment. The following subsections describe the conventional process and some of the more common variations which are not separate processes, but are operational variations of the same process with slightly different plant configurations.

Exhibit 1 lists some operating characteristics of activated sludge processes in section 53.13d.

56.11a - Conventional Activated Sludge

This process can reduce the BOD-5 by as much as 95 percent. It requires considerable operating control, can be upset rather easily, and is slow in returning to normal efficiency. The high sludge production rate also presents a sludge handling problem. Oxygen requirements of the micro-organisms are high. They must be supplied continuously with oxygen absorbed by the sewage in the aeration basin. Primary sedimentation is usually provided ahead of the aeration basin.

Three means of aeration and mixing are used: (1) diffused air and (2) mechanical, or (3) combination of the two. In the diffused air basin, compressed air is supplied through diffuser plates or diffuser tubes. About 95 to 98 percent of the air is used in mixing and agglomerating the solids, and the remainder is used for oxidation. Diffusers are susceptible to clogging. Mechanical aerators use impellers or revolving disks for agitating the sewage and transferring air to the sewage from the atmosphere.

The period of contact of sewage with the sludge is the detention time. The average detention time in aeration basins utilizing compressed air through diffuser plates or tubes is about 6 hours; in mechanical aeration basins it is about 8 hours.

1. Factors Affecting Biological Process. The degree of treatment depends upon proper control and adjustment of the biological process. Plant operators must determine by trial the best operating range of all factors involved and establish procedures by study, testing, and observation to meet variable conditions. The important factors are:

a. Raw sewage flow.

b. Quantity of air required for various loadings to maintain adequate dissolved oxygen content in the aeration basins.

c. Suspended solids concentration by dry weight in the aeration basin effluent.

d. Settling rate of solids in the aeration basin effluent.

e. Volume of activated sludge returned to aeration basins.

f. Suspended solids concentration by volume in return sludge.

g. Volume of activated sludge wasted compared to the raw sewage flow.

Good quality activated sludge settles rapidly, leaving a clear, odorless, stable liquid above; the sludge is brown in color and has a slight musty odor. The floc usually appears to be granular with sharply defined edges. A dense sludge is desirable.

These are several common difficulties associated with the activated sludge process. It is subject to shock loads. Large amounts of septic sewage or industrial waste can upset the process. Rapid fluctuation of influent temperature shows biological activity.

2. Causes of Bulking. One indication of an upset plant will be sudden loss of sludge density, known as sludge bulking. This is evidenced by a high sludge index, poor sludge settling in the clarifier, and passage of floc through the clarifier and out with the effluent. Bulking may be caused by:

a. Too high or too low solids concentration in the aeration tank.

b. Inadequate air supply or inadequate aeration period.

c. Sudden heavy loads exerted on the system by various industrial or concentrated wastes.

d. Fungus accumulations from the sanitary sewer system.

e. Abnormal nutrient balance in the sewage or waste.

In order to eliminate bulking, it is necessary to restore the proper balance between oxygen demand, oxygen supply, and the food to micro-organism ratio.

Occasionally sludge that has good settling characteristics will rise to the surface after a relatively short settling period because of denitrification, in which the nitrites and nitrates in the wastewater are converted by the micro-organisms to nitrogen gas. If enough gas is formed, the sludge mass becomes buoyant and rises to the surface. Rising sludge can be differentiated from bulking sludge by the presence of small gas bubbles attached to the floating solids. The rising sludge problem can usually be overcome by one of several simple changes in operational procedures.

A modest accumulation of fresh, crisp, white foam on the aeration basin is usually a good sign of a well operated system that is producing a good effluent. Thick billows of white sudsy form may indicate that the sludge age is too low or it can also indicate the presence of a non-biodegradable surface active material, for example, from a cleaning compound. A dense and somewhat greasy and scummy layer of deep tan to brown foam may indicate an old sludge or one that is overoxidized.

Initial startup of an activated sludge plant or restart following a seasonal shutdown can vary between a few days to several weeks. This is the time required to begin producing good quality effluent. The longer period would be needed if the natural buildup of the micro-organisms is desired. A shorter time is required if "seed" sludge from another activated sludge plant is introduced to the plant.

56.11b - Extended Aeration

Extended aeration plants are used for treatment of relatively small flows of 10,000 to 100,000 gpd to overcome some of the limitations associated with the conventional activated sludge. Individual home size extended aeration package plants are available in capacities increasing upward from about 500 gpd.

The aeration period is usually a minimum of 24 hours. In the latter stages of aeration, the sludge food source is depleted and the sludge breaks itself down, undergoing endogenous respiration. This results in a highly treated effluent with relatively low sludge production. Oxygen demand may be more than twice that of the conventional activated sludge process. BOD-5 reductions of 75 to 90 percent can generally be expected for normal domestic wastes with a pant having proper maintenance. Larger tank volumes are needed to hold the wastes for the extended time. A sludge storage tank is usually provided. Other plant features are similar to the conventional activated sludge plant.
The extended aeration modification is suited to some Forest Service applications. However, seasonal facilities can cause severe operational problems with this type of treatment due to fluctuation flows.

Probably the most common problem is when the plant becomes "upset" for any reason. When this happens, suspended solids increase, effluent quality decreases, and micro-organisms are lost. Once upset, the plant can take from a few days to several weeks to return to normal operation depending on the severity of the problem. Proper operator attention can usually reduce the severity.

56.11c - Contact Stabilization

Two separate aeration tanks are used to provide two-stage sludge aeration. This takes advantage of the great adsorptive capacity of activated sludge floc. A short (15 to 30 min.) "contact" stage is used during which a major portion of the applied BOD-5 is transferred from the wastewater to the sludge solids. The mixture is then passed through a clarifier where the sludge is separated from the treated liquid. From there, the sludge goes to a reaeration tank for 4 to 8 hours.

BOD-5 reduction around 85 percent is normal. The primary advantage of this process is the smaller tank volume required for an identical loading on a conventional activated sludge plant. In addition, contact stabilization can handle shock loads because of the biological buffering capacity of the reaeration tank, and the fact that at any given time the majority of the activated sludge is isolated from the main stream of the plant flow. An existing hydraulically overloaded conventional activated sludge plant can usually be upgraded to contact stabilization. This type of process is generally not used for areas of less than 2,000 population, or a flow of less than 100,000 gpd.

56.11d - Oxidation Ditch

The oxidation ditch is an extended aeration process using a long narrow continuous channel as the aeration basin. The channel is oval or circular with a paddlewheel or brush-type aerator. The ditch is followed by a clarifier. A removable baffle placed across a compartmented half-width of the aeration channel may also be used for a clarifier. Part of the sludge is returned to the ditch.

This process is able to withstand shock and peak loads, and can be operated continuously or intermittently. Operation and maintenance is relatively simple compared to other activated sludge processes.

One disadvantage of this process is the large land area required.

56.12 - Biofilter Systems

These processes accomplish waste stabilization through aerobic micro-organisms growing on a filter medium. The media used can be natural (rock) or synthetic (plastic), and be either stationary (trickling) or moving (rotating).

The quantity of biological slime produced on the media is controlled by the available organic wastes, and the growth will increase as the organic load increases until a maximum thickness is reached. The biological slime growth is affected by hydraulic loading rate, ventilation, type of media, type of organic matter, amount of essential nutrients present, temperature, pH, and the nature of the particular biological growth.

56.12a - Trickling Filters

Trickling filtration consists of uniform distribution of wastewater over the trickling filter media by a flow distributor. A large portion of the wastewater applied to the filter passes rapidly through it, and the remainder trickles slowly over the surface of the biological slime. BOD-5 removal occurs by biosorption and coagulation from the rapidly moving portion of the flow, and by progressive removal of soluble constituents from the more slowly moving portion of the flow.

The ideal filter medium is a material that has a high surface area per unit of volume, is low in cost, has a high durability, and does not clog easily. A locally available crushed stone or gravel graded to a uniform size within the range of 1 to 3 inches is good. Stones less than 1 inch in diameter do not provide sufficient pore space between the stones to permit free flow of sewage and sloughed solids. Large diameter stones have a relatively small surface area per unit volume; thus they cannot support as large a biological population. Plastic media has also been used successfully.

The process is preceded by a primary sedimentation tank and followed by a final sedimentation tank. A distribution system applies the primary effluent to the medium, and an underdrain system discharges the treated wastewater and provides ventilation. Operation of trickling filters is relatively simple and does not require as highly skilled operators as activated sludge plants; howver, they are less efficient than activated sludge plants, and the effluent may be of a lower quality.

Trickling filters do not lend themselves to normal Forest Service use because of several operational characteristics. Intermittent loading of these filters is probably the greatest threat to a successful process. If the micro-organisms are washed off the media because of high flows, the process breaks down. Similar process failure occurs if the media dries out and the mirco-organisms slough off because of very low or no flows. Some sloughing is part of the normal filter operation, but excessive sloughing causes problems.

Other operational problems are:

1. Filter ponding caused by clogged voids.

2. Filter flies developing in an alternately wet and dry environment.

3. Odors caused when the process changes from aerobic to anaerobic conditions.

4. Icing of filter surface caused by cold weather. Cold weather also reduces the filter efficiency.

5. Clogging of distributor arm orifices caused by non-uniform flow.

6. Snails, moss, and roaches most common in the South can lead to filter clogging and be a general nuisance.

Trickling filters are classified by hydraulic or organic loading as high-rate or low-rate. High-rate trickling filters can maintain a relatively constant loading by recirculating the

wastewater. The higher organic loadings in these filters preclude the development of nitrifying bacteria in the lower section of the filter. Hence, these plants will seldom exhibit any nitrification and will generally not perform as well as low-rate filters. Exhibit 2 lists some comparisons between low-rate and high-rate trickling filters in section 53.13d.

56.12b - Rotating Biological Filters

In these systems, known as RBC's, the sewage moves horizontally through a tank in which large diameter thin plastic discs rotate. The filters (discs) are partially immersed in the wastewater. As they rotate, a film of wastewater is carried into the air and then trickles down the surface of the filter, absorbing oxygen from the air.

As the attached micro-organisms pass through the wastewater, some are stripped from the filter into the mixed liquor. This prevents clogging of the media surfaces and maintainns a constant micro-organism population. Some form of pretreatment removal is necessary preceding the filter to keep raw sewage solids from plugging the filter.

This type filter does not require complicated operational procedures. Its operational functions make it suitable for Forest Service installations.

Wide variations in wastewater flow rates may be treated effectively without significant loss of culture and without substantial upset. However, prolonged increases in flow rate will lead to poor performance. Like extended aeration, the overall effluent quality achieved is a factor of both the biooxidation and and settlement stages.

Some operational factors that may adversely affect process efficiency are:

1. Reduced wastewater temperatures below 13 C (55 F).

2. Unusual variation in flow and/or organic loading.

3. pH of wastewater outside the range of 6.5 to 8.5.

4. Accumulation of solids in the filter may block passage of wastewater.

56.13 - Lagoon Systems

Lagoons are biological waste treatment systems in which algal photosynthetic and bacterial oxidation are effective in stabilizing a portion of the organic material in wastewater. The process is controlled to a large extent by climatic conditions, primarily temperature and wind action.

A lagoon system can include a single pond or a number of ponds in series or parallel. Series operation is beneficial where a high level of BOD or coliform removal is important. The effluent from facultative ponds in series operation has a much lower algal concentration than that obtained in parallel operation. Parallel ponds provide

better distribution of settled solids. Smaller ponds are conducive to better circulation and have less wave action.

Lagoons operated in series minimize the possibility of short-circuiting and the discharge of partially treated effluent. In general, the effluent of the last lagoon of a series is of better quality than that from a single lagoon which had the same detention time as the lagoons in series.

The environment within the pond and the purpose for which the pond is used are the bases for classification of lagoons. The four classes are facultative, aerobic, anaerobic, and aerated.

Lagoon construction ranges from aboveground dikes impounding the water to steel and concrete tanks.

Th reliability of lagoons is high because mechanical equipment is not needed except for aerated lagoons. This makes lagoons suitable for larger Forest Service applications. Land requirements are relatively large an may limit lagoon use in mountainous areas where other land uses have priority on level areas.

The design of lagoons is based essentially upon the total quantity of wastewater to be treated and the influent BOD concentration. It is also essential that any industrial wastes or toxic materials present in the incoming wastewater be identified and treated to minimize potential toxic effects on the algae. Lagoons must be located and constructed to exclude surface runoff. The basic design information required includes:

1. Total wastewater flow per day, including seasonal variations.
2. Concentration of BOD.
3. Ratio of 5-day BOD to ultimate BOD.
4. The minimum and maximum air tempertures.
5. If freezing occurs, the duration of time during which an ice cover can be expected.
6. The presence of any potentially toxic material.
7. If septage or vault toilet waste is to be disposed of in the lagoon, the quantity and characteristics of the waste.
8. Rainfall and evaporation.

Some problems in the operation of lagoons are actually design problems and little can be done to correct them at the operational stage. These are: overloading; low ambient temperatures; toxic materials in the infuent; and insufficient detention time. Common operational problems are: ice formation; excessive loss of liquid volume; excessive

plant growth; excessive turbidity from storm flows; an an operating level too deep for light penetration.

Environmental nuisances associatd with lagoons are: odors caused by anaerobic conditions and springtime turnover; foaming and spraying in aerated lagoons; insects; and groundwater contamination from leakage.

Hazardous conditions around lagoons may e caused by: bank and dike erosion from wave action or flow of adjacent streams; burrows of small wildlife; an root growths from woody plants and trees that furnish pathways for leakage.

56.13a - Facultative Lagoons

The terms standard lagoon and oxidation ponds are synonymous with facultative lagoons. Raw or partially treated wastewater is fed into the lagoon. Sunlight penetrating the upper level of the water encourages algae growth. The algae produce oxygen through photosynthesis which is used by aerobic bacteria to stabilize the organic material and some algae. Aerobic bacteria operate in the upper layers of water while anaerobic bacteria operate at the bottom.

Generally, there is no supplemental or mechanical addition of air to the system. However, in some instances it may be desirable or necessary to aerate the upper layer of water to maintain the facultative micro-organisms. When this is done, it is called incomplete mixing or a mechanically aerated facultative lagoon.

A facultative lagoon designed for no effluent is called non-overflow. Evaporation is the vehicle used to dispose of what normally would become effluent.

56.13b - Aerobic Lagoons

Aerobic biological stabilization takes place under the action of aerobic micro-organisms and algae. The carbon dioxide from the oxidized organic matter is used by the algae in the presence of sunlight to form new algal cells. Aerobic lagoons are generally free of odors if they are not overloaded.

The right combination of physical and organic conditions existing in an aerobic lagoon may cause the lagoon to become facultative with anaerobic action in the lower layers of the water. As these conditions change, the biological action may return to aerobic. There is a fine line of distinction between aerobic and facultative lagoons, with only the presence of facultative micro-organisms and the anaerobic action in the bottom of a facultrative lagoon being the distinction.

56.13c - Anaerobic Lagoons

The processes acting in an anaerobic lagoon are the same that occur in septic tanks and Imhoff tanks. This involves the sequential activity of facultative micro-organisms and methane forming bacteria. The primary factors affecting the growth of methane

bacteria are temperature, pH, detention time, and organic loading rate. Methane bacteria grow relatively slowly compared to facultative micro-organisms and require much longer detention times for development of an adequate population. The facultative bacteria use the dissolved oxygen in the environment and protect the methane bacteria from exposure to oxygen. Sufficient volume is necessary for the storage of sludge resulting from the accumulation of settled solids.

Anaerobic lagoons have essentially no operation an maintenance. Seasonal odors may be present. An anaerobic lagoon can be used as a preliminary treatment preceding an aerobic or facultative system.

56.13d - Aerated Lagoons

This is essentially an activated sludge process without recycle. With aeration, higher loadings, shorter detention times, and greater depths than in facultative lagoons are possible. Aerated lagoons are not dependent on algae as the oxygen source; consequently, they can function without sunlight. Oxygen and mixing is usually acccomplished by diffused, submerged turbine, or surface aerators. The aeration is also called complete mixing. Clarification is required following an aerated lagoon.

In some instances, a facultative or aerobic lagoon may be converted to an aerated lagoon by the addition of aerators. Aerated lagoons can be phase constructed beginning with a facultative or incomplete mix and ending with an aerated or complete mix lagoon.

Exhibit 3 lists some comparisons of lagoons.

***-Exhibit 1**

CHARACTERISTICS OF ACTIVATED SLUDGE WASTE TREATMENT AND TWO MODIFICATIONS

Name of Process Modification	Plant Design Flow Range, GPD	Aeration Period in Hours (Based on Design Flow)	BOD-5 Removal Percentage
Conventional Activated Sludge	100,000 - 500,000	6.0 - 7.5	85 - 95
Contact Stabilization	100,000 - 500,000+	1.5 - 3.0	80 - 90
Extended Aeration	10,000 - 100,000	24	75 - 90

***-Exhibit 2**

SOME COMPARISONS OF LOW-RATE AND HIGH-RATE TRICKLING FILTERS

Factor	Low-rate filter	High-rate filter
Hydraulic loading, mg/d	1 to 4	10 to 40
Organic loading, 1b BOD-5/acre-ft-day	300 to 1,000	1,000 to 5,000
Depth, ft	6 to 10	3 to 8
Recirculation	None	1:1 to 4:1

***-Exhibit 3**

COMPARISON OF LAGOONS

	Aerobic & Faculative	Anaerobic	Aerated
Lagoon Depth, ft	2 - 5	2 - 15	10 - 15*
Typical Surface Loading, 1b BOD/ Day/Acre	20(Northern U.S.)** 50(Southern U.S.)**	200 - 500	75 - 2700
Typical Detention Time, Days	50 - 60	20 - 50	3 - 10
BOD Removal, Percent	70 - 90	60 - 80	75 - 85

* Addition of anti-erosion plates on surface aerators may allow a reduced depth, but efficiency decreases.

** See EPA Process Design Manual, "Wastewater Treatment Facilities for Sewered Small Communities."

57 - Tertiary Treatment

Tertiary treatment is the further processing or polishing of the wastewater effluent from a primary or secondary process. Tertiary treatment is designed to remove dissolved and suspended material by means other than simple gravitation or mechanical screening. Tertiary processes are often variations of primary or secondary processes but may also be entirely different from them. In any case, they are applied in addition to the primary or secondary process but may be physically located any place in the process train.

57.1 - Suspended Solids Removal

Tertiary removal of suspended solids is generally accomplished either by microscreening or by filtration. Chemical coagulation often precedes filtration but is not usually practical with microscreening since the floc is apt to shear in the screen.

57.11 - Microscreening

Microscreens consist of rotating cylindrical drums covered with a woven metal fabric, usually of 316 or 18/8 stainless steel, through which the wastewater flows from the inside out. Solids are removed by a continuous wash and are returned to the secondary process. Ultraviolet lights or a chlorine wash are often employed to inhibit the formation of biologic growths on the screens. Screen openings from 3 mm to about 20 microns are available with the finer mesh being able to produce an effluent having 4-10 mg/1 suspended solids. The BOD varies according to the percent of biodegradables present and the extent of oxidation which has occurred.

The screens are subject to stoppage from grease, and means have been devised to pressure backwash them when the headloss across the fabric becomes excessive.

The sizing of screens is not merely based on the desired flow divided by the allowable flow per square foot since the solids concentration in the influent stream is a determining factor as well as speed of rotation and allowance for collected mat. Various methods have been devised by the manufacturers for sizing the screens, and these should be consulted.

57.12 - Filtration

Diatomaceous earth filters are generally too costly for treatment of wastewaters, and their few proper applications are not relevant to Forest Service needs. Ultra-filtration probably is better discussed along with the membrance processes, but it, too, has little application to Forest Service problems. Cartridge filters are relatively standard and require little more than manufacturer's data to determine their applicability. Granular filters, however, come in various kinds and their design can be crucial to the success of the treatment plant design. The following paragraphs, therefore, are concerned with this latter type.

Tertiary filters are usually employed in one of three locations within the treatment sequence. The first location follows the secondary treatment process, and the filters are intended to remove additional suspended solids and BOD_5. A second location is one following an aerobic packed bed reactor intended for reduction of both ammonia and BOD_5. The third location for the tertiary filter is one following an anaerobic packed bed reactor for nitrate reduction when that is preceded by an aerobic packed bed reactor used for ammonia reduction.

Optimum capital cost of filters is obtained with the highest net yield (out-flow minus backwash) which produces an acceptable effluent. This means that longer filter runs must be balanced against flow rate to reduce costs. This is the principal difficulty in applying experience gained in water treatment to wastewater filtration. The highly variable solids content and flow rates of wastewaters require other considerations and design parameters than do the relatively stable values encountered in water treatment.

The decision as to whether the filter should be a pressure filter or gravity is largely one of availability of head and the economics of size. These must be matched to the individual plant requirements.

1. Intermittent Sand Filters. These are seldom used now and are particularly unsuitable for large installations. Part of the reason is the high initial cost and the fact that they must be periodically skimmed manually to remove the collected mat of material removed from the wastewater.

The filter consists of a bed of uniformly graded sand underlain with a drain system. Wastewater is periodically spread on the sand surface and allowed to percolate through the sand to be led off by the underdrains. Normally, the wastewater is spread once a day, but some installations admit the wastewater as often as four times daily. There are no controls on the outflow since the flow rate is determined by the depth of flooding, porosity of the bed, effect of the collected mat, and the concentration of solids in the wastewater. Removal efficiency is good, but the yield per square foot is small. They have been used with some success to polish septic tank effluent, but odors can be a problem. In this application, it is usual to use natural sand without a graded design to reduce the cost of construction.

2. Conventional Sand Filters. Wastewater is admitted to the upper side of the filter bed, which is graded from fine sand at the top to coarser sand at the bottom. This grading is the result of the backwash necessary to remove the collected solids. When the particles of sand settle after the backwash, they settle with the finer grains at the top. This gradation makes the filter unsuitable to high influent solids concentration since the solids collect immediately at the top surface. Longer filter runs require that filtration occur in depth, that is, the upper layers of the filter are coarser to permit solids to collect in depth rather than at the first surface of contact.

3. Upflow Filters. The objections to the conventional sandfilter can be somewhat overcome by the use of the upflow filter. In this instance, the coarser sand at the

bottom first contacts the wasterwater which is admitted at the bottom. The coarser sand is overlain with a deep bed of uniformly graded fine sand. In this manner, filtration in depth is achieved. The difficulty in this arrangement is that the incoming flow tends to lift the filter bed and create objectionable stratification. This can be somewhat overcome by placing a metal grid over the top of the filter bed to hold it in place. This type filter is popular in European practice.

4. Bi-Flow Filters. Difficulties in keeping the filter bed of upflow filters in place can also be solved by introducing the wastewater at both top and bottom of the filter, thus tending to balance the forces which would displace the bed. The outflow occurs from the center of the bed. This type filter apparently is not in extensive use, probably because the upper portion of the bed must be constructed differently from the bottom portion. The upper portion has the same disadvantages as the conventional sandfilter and has a different yield from that of the bottom portion. The quality of effluent from the two portions also apparently differs.

5. Single Media Filters. Another method of filter construction is that employing a single-size media of rather coarse sand. This overcomes the objection of stratification with backwash as well as permitting some filtration in depth. Backwash is effected with both air and water to scrub out the collected matter without bed expansion. Single media filters are more common in European practice than in the United States.

6. Dual Media Filters. These are the most common in United States practice but are seldom used in tertiary treatment. A layer of anthracite coal overlays the sand bed to provide the filtration in depth. In backwashing, the flow must be great enough to fully expand the bed and assure that the coal settles at the top. This often requires higher backwash rates.

7. Multi-Media Filters. When three media are employed, the filters are variously referred to as "multi-media," "triple media," and as "mixed media" filters. The multi-media filter is a patented item and gets its various names because the three media (coal, sand, and garnet or illmenite) are graded to partially intermix. This reduces the tendency for "breakthrough" at higher flow rates more common to dual media filters. Filters of five and more media have been developed but are not in common use.

Must filters must be backwashed and various methods have been devised to accomplish the cleaning and desired stratification or lack of it. The media must be selected by size and specific gravity to match the backwash rate and to provide the necessary filtration in depth. Air is sometimes combined with water in the backwash to enhance the cleaning, but its effectiveness is doubted by some. It appears not to significantly reduce the amount of water required, complicates the cycle, and increases the risk of media loss.

57.2 - Dissolved Organics Removal

At this time, the most practical method for the removal of dissolved organics is the use of activated carbon. Some resins have been developed which seem to effectively adsorb organics common to domestic wastewaters but most are irreversibly fouled. Detergents seem to be the most common threat, but other organics pose serious problems in demineralization processes, which will be discussed later in this chapter. Foam fractionation and distillation are not considered to be realistic alternatives for Forest Service applications.

While activated carbon is used most often for the removal of dissolved organic material, it also is effective in removing some inorganic material, including several of the metals. Removal of cadmium, chromium, lead, trivalent iron, silver, mercury, titanium, and zirconium, among others, can be achieved with activated carbon.

Activated carbon is produced by two methods: thermal and chemical. Thermal activation requires heating the raw material to a high temperature in the presence of an oxidizing gas, usually steam. Chemical activation uses a dehydrating agent in place of the oxidizing agent. The principal raw materials used are sawdust, charcoal, coconut shell, lignite, bituminous coal, petroleum coke, and black ash.

Removal of dissolved organics is accomplished by adsorption on the surface of the carbon particles. The available surface area varies from 450 to 1800 m^2/gm. The pore volume varies from 0.7 to 1.8 ml/gm. With the exception of that made from coconut shell, most activated carbon is relatively inexpensive.

Activated carbon is available in two forms: powdered and granular. Powdered carbon is used by mixing it with the liquid while the granular form is placed in a column and the liquid passed through it. Powdered carbon is retrieved by means of a filter and is usually wasted. Recently, however, several processes have become available which apparently make the regeneration of powdered carbon practical. Granular carbon is usually regenerated and reused. In the larger installations, the regeneration is accomplished on site, while the smaller ones can have it done on a contract basis. Granular carbon is more prevalent in industrial processes, but the choice is based on a comparison of carbon cost, capital investment, process arrangement, cleanliness, and disposal of the waste carbon.

For large installations, column tests are generally required to evaluate the performance of selected carbons as well as to determine parameters necessary to design to a particular wastewater. For most Forest Service installations, this may not be practical, but an evaluation of manufacturers' data, at least, is necessary. Characteristics to be compared include surface area, apparent density, bulk density, effective size, pore volume, sieve analysis, abrasion number, ash percentage, iodine number, molasses number, and pore size distribution. Normal design parameters for tertiary treatment are:

Contact Time	10-50 minutes
Hydraulic Loading	2-10 gpm/sq.ft.
Backwash Rate	15-20 gpm.sq.ft.
Carbon Requirement	200-500 lbs/MG
Weight COD removed/ weight carbon	0.3-0.8 lb./lb.