United States
Environmental Protection
Agency

EPA

Onsite Wastewater Treatment Systems Manual

Sludge-handling process

To reduce loading to the liquid stream, the septage can be sent directly to the sludge-handling process. Like the headworks option, the impact on the sludge treatment processes must be carefully analyzed to ensure that the final product meets treatment and other requirements.

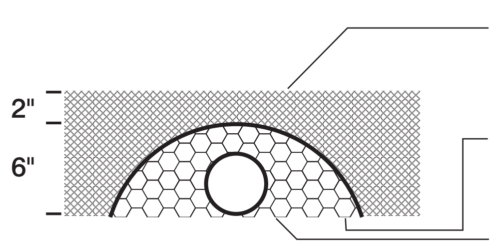
Treatment at a special septage treatment plant

This method of septage disposal is usually employed in areas where land disposal or treatment at a wastewater treatment plant is not a feasible option. There are few of these facilities, which vary from simple lagoons to sophisticated plants that mechanically and/or chemically treat septage. Treatment processes used include lime stabilization, chlorine oxidation, aerobic and anaerobic digestion, composting, and dewatering using pressure or vacuum filtration or centrifugation. This is the most expensive option for septage management and should be considered only as a last resort.

Public outreach and involvement

Developing septage treatment units or land application sites requires an effective public outreach program. Opposition to locating these facilities in the service area is sometimes based about incomplete or inaccurate information, fear of the unknown, and a lack of knowledge on potential impacts. Without an effective community-based program of involvement, even the most reasonable plan can be difficult to implement. Traditional guidance on obtaining public input in the development of disposal or reuse facilities can be found in *Process Design Manual: Surface Disposal of Sewage Sludge and Domestic Septage* (USEPA, 1995b), which is on the Internet at **http://www.epa.gov/ORD/WebPubs/sludge.pdf**.

Figure 4-25. Underdrain system detail for sand filters



Additional information can be found in *Domestic Septage Regulatory Guidance* (USEPA, 1993), posted at **http://www.epa.gov/oia/tips/scws.htm**. General guidance on developing and implementing a public outreach strategy is available in *Getting In Step: A Guide to Effective Outreach in Your Watershed*, published by the Council of State Governments (see chapter 2) and available at **http://www.epa.gov/owow/watershed/outreach/documents/**.

4.7 Sand/media filters

Sand (or other media) filters are used to provide advanced treatment of settled wastewater or septic tank effluent. They consist of a lined (lined with impervious PVC liner on sand bedding) excavation or watertight structure filled with uniformly sized washed sand (the medium) that is normally placed over an underdrain system (figure 4-25). These contained media filters are also known as packed bed filters. The wastewater is dosed onto the surface of the sand through a distribution network and is allowed to percolate through the sand to the underdrain system. The underdrain collects the filtrate for further processing, recycling, or discharging to a SWIS. Some “bottomless” designs directly infiltrate the filtered effluent into the soil below.

4.7.1 Treatment mechanisms and filter design

Sand filters are essentially aerobic, fixed-film bioreactors used to treat septic tank effluent. Other very important treatment mechanisms that occur in sand filters include physical processes such as straining and sedimentation, which remove suspended solids within the pores of the media, and chemical adsorption of dissolved pollutants (e.g., phosphorus) to media surfaces. The latter phenomenon tends to be finite because adsorption sites become saturated with the adsorbed compound, and it is specific to the medium chosen. Bioslimes from the growth of microorganisms develop as attached films on the sand particle surfaces. The microorganisms in the slimes absorb soluble and colloidal waste materials in the wastewater as it percolates around the sand surfaces. The absorbed materials are incorporated into new cell mass or degraded under aerobic conditions to carbon dioxide and water.

Most of the biochemical treatment occurs within approximately 6 inches (15 centimeters) of the filter surface. As the wastewater percolates through this active layer, carbonaceous BOD and ammonium-nitrogen are removed. Most of the suspended solids are strained out at the filter surface. The BOD is nearly completely removed if the wastewater retention time in the sand media is sufficiently long for the microorganisms to absorb and react with waste constituents. With depleting carbonaceous BOD in the percolating wastewater, nitrifying microorganisms are able to thrive deeper in this active surface layer, where nitrification will readily occur.

To achieve acceptable treatment, the wastewater retention time in the filter must be sufficiently long and reaeration of the media must occur to meet the oxygen demand of the applied wastewater. The pore size distribution and continuity of the filter medium, the dose volume, and the dosing frequency are key design and operating considerations for achieving these conditions. As the effective size and uniformity of the media increases, the reaeration rate increases, but the retention time decreases. Treatment performance might decline if the retention time is too short. If so, it may be necessary to recirculate the wastewater through the filter several times to achieve the desired retention time and concomitant treatment performance. Multiple small dose volumes that do not create a saturated wetting front on the medium can be used to extend residence times. If saturated conditions are avoided, moisture tensions within the medium will remain high, which will redistribute the applied wastewater throughout the medium, enhancing its contact with the bioslimes on the medium. The interval between doses provides time for reaeration of the medium to replenish the oxygen depleted during the previous dose.

Filter surface clogging can occur with finer media in response to excessive organic loadings. Biomass increases can partially fill the pores in the surface layer of the sand. If the organic loadings are too great, the biomass will increase to a point where the surface layer becomes clogged and is unable to accept further wastewater applications. However, if the applied food supply is less than that required by resident microorganisms, the microorganisms are forced into endogenous respiration; that is, they begin to draw on their stored metabolites or surrounding dead cells for food. If the microorganisms are maintained in this growth phase, net increases of biomass do not occur and clogging can be minimized.

Chemical adsorption can occur throughout the medium bed, but adsorption sites in the medium are usually limited. The capacity of the medium to retain ions depends on the target constituent, the pH, and the mineralogy of the medium. Phosphorus is one element of concern in wastewater that can be removed in this manner, but the number of available adsorption sites is limited by the characteristics of the medium. Higher aluminum, iron, or calcium concentrations can be used to increase the effectiveness of the medium in removing phosphorus. Typical packed bed sand filters are not efficient units for chemical adsorption over an extended period of time. However, use of special media can lengthen the service (phosphorus removal) life of such filters beyond the normal, finite period of effective removal.

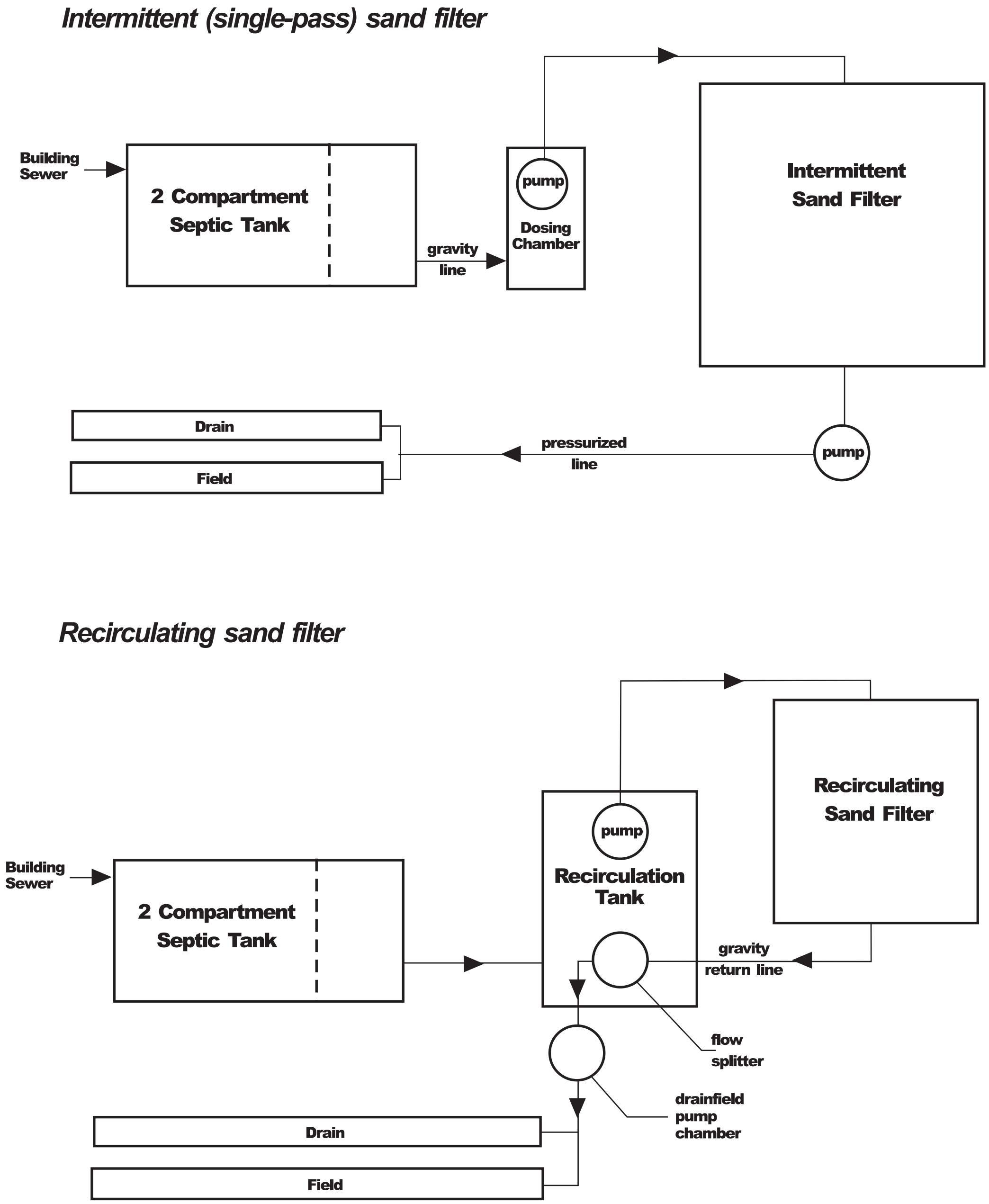
Filter designs

Sand filters are simple in design and relatively passive to operate because the fixed-film process is very stable and few mechanical components are used. Two types of filter designs are common, “single-pass” and “recirculating” (figure 4-26). They are similar in treatment mechanisms and performance, but they operate differently. Single-pass filters, historically called “intermittent” filters, discharge treated septic tank effluent after one pass through the filter medium (see Fact Sheet 10). Recirculating filters collect and recirculate the filtrate through the filter medium several times before discharging it (see Fact Sheet 11). Each has advantages for different applications.

Single-pass filters

The basic components of single-pass filters (see Fact Sheet 10) include a dose tank, pump and controls (or siphon), distribution network, and the filter bed with an underdrain system (figure 4-25). The wastewater is intermittently dosed from the dose tank onto the filter through the distribution network. From there, it percolates through the sand medium to the underdrain and is discharged. On-demand dosing has often been used, but timed dosing is becoming common.

Figure 4-26. Schematics of the two most common types of sand media filters



To create the wastewater retention times necessary for achieving desired treatment results, single-pass filters must use finer media than that typically used in recirculating filters. Finely sized media results in longer residence times and greater contact between the wastewater and the media surfaces and their attached bioslimes. BOD removals of greater than 90 percent and nearly complete ammonia removal are typical (Darby et al., 1996; Emerick et al., 1997; University of Wisconsin, 1978). Single-pass filters typically achieve greater fecal coliform removals than recirculating filters because of the finer media and the lower hydraulic loading. Daily hydraulic loadings are typically limited to 1 to 2 gpd/ft^2, depending on sand size, organic loading, and especially the number of doses per day (Darby et al., 1996).

Recirculating filters

The basic components of recirculating filters (see Fact Sheet 11) are a recirculation/dosing tank, pump and controls, a distribution network, a filter bed with an underdrain system, and a return line fitted with a flow-splitting device to return a portion of the filtrate to the recirculation/dosing tank (figure 4-26). The wastewater is dosed to the filter surface on a timed cycle 1 to 3 times per hour. The returned filtrate mixes with fresh septic tank effluent before being returned to the filter.

Media types

Many types of media are used in packed bed filters. Washed, graded sand is the most common medium. Other granular media used include gravel, anthracite, crushed glass, expanded shale, and bottom ash from coal-fired power plants. Bottom ash has been studied successfully by Swanson and Dix (1987). Crushed glass has been studied (Darby et al., 1996; and Emerick et al., 1997), and it was found to perform similarly to sand of similar size and uniformity. Expanded shale appears to have been successful in some field trials in Maryland, but the data are currently incomplete in relation to long-term durability of the medium.

Foam chips, peat, and nonwoven coarse-fiber synthetic textile materials have also been used. These are generally restricted to proprietary units. Probably the most studied of these is the peat filter, which has become fairly common in recent years. Depending on the type of peat used, the early performance of these systems will produce an effluent with a low pH and a yellowish color. This is accompanied by some excellent removal of organics and microbes, but would generally not be acceptable as a surface discharge (because of low pH and visible color). However, as a pretreatment for a SWIS, low pH and color are not a problem. Peat must meet the same hydraulic requirements as sand (see Fact Sheets 10 and 11). The primary advantage of the proprietary materials, the expanded shale, and to some degree the peat is their light weight, which makes them easy to transport and use at any site. Some short-term studies of nonwoven fabric filters have shown promise (Roy and Dube, 1994). System manufacturers should be contacted for application and design using these materials.

4.7.2 Applications

Sand media filters may be used for a broad range of applications, including single-family residences, large commercial establishments, and small communities. They are frequently used to pretreat wastewater prior to subsurface infiltration on sites where the soil has insufficient unsaturated depth above ground water or bedrock to achieve adequate treatment. They are also used to meet water quality requirements before direct discharge to a surface water. They are used primarily to treat domestic wastewater, but they have been used successfully in treatment trains to treat wastewaters high in organic materials such as those from restaurants and supermarkets. Single pass filters are most frequently used for smaller applications and sites where nitrogen removal is not required. Recirculating filters are used for both large and small flows

Performance of sand and other filters

Twelve innovative treatment technologies were installed to replace failed septic systems in the Narragansett Bay watershed, which is both pathogen- and nitrogen-sensitive. The technologies installed consisted of an at-grade recirculating sand filter, single pass sand filters, Maryland-style recirculating sand filters, foam biofilters, and a recirculating textile filter. The treatment performance of these systems was monitored over an 18-month period. In the field study, TSS and BOD_5 concentrations were typically less than 5 mg/L for all sand filter effluent and less than 20 mg/L for both the foam biofilter and textile filter effluents. Single pass sand filters achieved substantial fecal coliform reductions, reaching mean discharge levels ranging from 200 to 520 colonies per 100 mL for all 31 observations. The at-grade recirculating sand filter achieved the highest total nitrogen reductions of any technology investigated and consistently met the Rhode Island state nitrogen removal standard (a TN reduction of 50 percent or more and a TN concentration of 19 mg/L or less) throughout the study.

Source: Loomis et al., 2001.

and are frequently used where nitrogen removal is necessary. Nitrogen removal of up to 70 to 80 percent can be achieved if an anoxic reactor is used ahead of the recirculation tank, where the nitrified return filtrate can be mixed with the carbon-rich septic tank effluent (Anderson et al., 1998; Boyle et al., 1994; Piluk and Peters, 1994).

4.7.3 Performance

The treatment performance of single-pass and recirculating filters is presented in table 4-16. The medium used was sand or gravel as noted. Recirculating sand filters generally match or outperform single-pass filters in removal of BOD, TSS, and nitrogen. Typical effluent concentrations for domestic wastewater treatment are less than 10 mg/L for both BOD and TSS, and nitrogen removal is approximately 50 percent. Single-pass sand filters can also typically produce an effluent of less than 10 mg/L for both BOD and TSS. Effluent is nearly completely nitrified, but some variability can be expected in nitrogen removal capability. Pell and Nyberg (1989) found typical nitrogen removals of 18 to 33 percent with their intermittent sand filter. Fecal coliform removal is somewhat better in single pass filters. Removals range from 2 to 4 logs in both types of filters. Intermittent sand filter fecal coliform removal is a function of hydraulic loading; removals decrease as the loading rate increases above 1 gpm/ft^2 (Emerick et al., 1997).

Effluent suspended solids from sand filters are typically low. The medium retains the solids. Most of the organic solids are ultimately digested. Gravel filters, on the other hand, do not retain solids as well.

excessive solids buildup due to the lack of periodic sludge pumping and removal. In such cases, the solids storage capacity of the final settling compartment might be exceeded, which results in the discharge of solids into the effluent. ATU performance and effluent quality can also be negatively affected by the excessive use of toxic household chemicals. ATUs must be properly operated and maintained to ensure acceptable performance.

4.8 Aerobic treatment units

Aerobic treatment units (ATUs) refer to a broad category of pre-engineered wastewater treatment devices for residential and commercial use. ATUs are designed to oxidize both organic material and ammonium-nitrogen (to nitrate nitrogen), decrease suspended solids concentrations and reduce pathogen concentrations.

A properly designed treatment train that incorporates an ATU and a disinfection process can provide a level of treatment that is equivalent to that level provided by a conventional municipal biological treatment facility. The AUT, however, must be properly designed, installed, operated and maintained.

Although most ATUs are suspended growth devices, some units are designed to include both suspended growth mechanisms combined with fixed-growth elements. A third category of ATU is designed to provide treatment entirely through the use of fixed-growth elements such as trickling filters or rotating biological contactors (refer to sheets 1 through 3). Typical ATU's are designed using the principles developed for municipal-scale wastewater treatment and scaled down for residential or commercial use.

Most ATUs are designed with compressors or aerators to oxygenate and mix the wastewater. Partial pathogen reduction is achieved. Additional disinfection can be achieved through chlorination, UV treatment, ozonation or soil filtration. Increased nutrient removal (denitrification) can be achieved by modifying the treatment process to provide an anaerobic/anoxic step or by adding treatment processes to the treatment train.

4.8.1 Treatment mechanisms

ATUs may be designed as continuous or batch flow systems (refer to fact sheets 1 through 3). The simplest continuous flow units are designed with no flow equalization and depend upon aeration tank volume and/or baffles to reduce the impact of hydraulic surges. Some units are designed with flow-dampening devices, including air lift or float-controlled mechanical pumps to transfer the wastewater from the aeration tank to a clarifier. Other units are designed with multiple-chambered tanks to attenuate flow. The batch (fill and draw) flow system design eliminates the problem of hydraulic variation. Batch systems are designed to collect and treat wastewater over a period of time.

Table 4-16. Single pass and recirculating filter performance.

Reference	BOD Inf. (mg/L)	BOD Eff. (mg/L)	BOD % Rem.	TSS Inf. (mg/L)	TSS Eff. (mg/L)	TSS % Rem.	TKN Inf. (mg-N/L)	TKN Eff. (mg-N/L)	TKN % Rem.	TN Inf. (mg-N/L)	TN Eff. (mg-N/L)	TN % Rem.	Fecal Coliforms Inf. (#/100mL)	Fecal Coliforms Eff. (#/100mL)	Fecal Coliforms % Rem.	Comments [d,e]
Single Pass Filters																
Cagle & Johnson (1994)[a] California	160	2	98.75	73	16	78.08	61.8	5.9	90.45	61.8	37.4	39.48	1.14E+05	1.11E+02	99.90	Sand media: es=0.25-0.65 mm; uc=3-4. Design hydraulic loadings=1.2 gpd/ft^2 based on 150 gpd/bedroom. Actual flows not measured.
Effert, et al. (1985)[a] Ohio	127	4	96.85	53	17	67.92	--	--	--	41.5	37.5	9.64	2.19E+05	1.60E+03	99.27	Sand media: es=0.4 mm, uc=2.5. Average loadings=0.4 gpd/ft^2 / 0.42 lb BOD/1000ft Doses per day=3.3.
Ronayne, et al. (1982)[a] Oregon	217	3	98.62	146	10	93.15	57.1	1.7	97.02	57.5	30.3	47.30	2.60E+05	4.07E+02	99.84	Sand media: es=0.14-0.30 mm; uc=1.5-4.0. Average loadings=0.33-0.70 gpd/ft BOD/1000ft^2-day.
Sievers (1998)[a] Missouri	297	3	98.99	44	3	93.18	37	0.5	98.65	37.1	27.5	25.88	4.56E+05	7.30E+01	99.98	Sand media: not reported. Design hydraulic loading=1 gpd/ft^2. Daily flows not reported.
Recirculating Filters																
Louden, et al. (1985)[a] Michigan	150	6	96.00	42	6	85.71	55	2.3	95.82	55	26	52.73	3.40E+03	1.40E+01	99.59	Sand media: es=0.3 mm, uc=4.0. Average loadings=0.9 gpd/ft^2(forward flow) / 1.13 lb BOD/1000ft^2-day. Recirculation ratio=3:1. Dosed 4-6 times per hour. Open surface, sprinkler
Piluk & Peters (1994)[a] Maryland	235	5	97.87	75	8	89.33	--	--	--	57	20	64.91	1.80E+06	9.20E+03	99.49	Sand media: es=1 mm, uc=<2.5. Design hydraulic loading3.54 gpd/ft^2(forward flow). Actual flows not measured. Recirculation ratio=3:1. Doses per day=24.
Ronayne, et al. (1982)[a] Oregon	217	3	98.62	146	4	97.26	57.1	1.1	98.07	57.5	31.5	45.22	2.60E+05	8.50E+03	96.73	Sand media: es=1.2 mm, uc=2.0. Maximum hydraulic loading (forward flow)=3.1 gpd/ft Recirculation ratio=3:1-4:1. Doses/day=48.
Roy & Dube (1994)[a] Quebec	101	6	94.06	77	3	96.10	37.7	7.9	79.05	37.7	20.1	46.68	4.80E+05	1.30E+04	97.29	Gravel media: es=4.0, uc=<2/5. Design hydraulic loading (forward flow)=23.4 gpd/ft ratio=5:1. Doses per day=48. Open surface, winter operation.
Ayres Assoc. (1998a)[b] Wisconsin	601	10	98.34	546	9	98.35	65.9	3	95.45	65.9	16	75.72	>2500	6.20E+01	>98	Gravel media: pea gravel (3/8-in. dia.). Design hydraulic loading=15 gpd/ft^2 (forward flow). Recirculation ratio=3:1-5:1. Doses per day=72. Open surface, seasonal operation.
Owen & Bobb (1994)[c] Wisconsin	80	8	90.00	36	6	83.33	--	--	>95	--	--	--	--	--	--	Sand media: es=1.5 mm, uc=4-5. Design hydraulic loading=2.74 gpd/ft^2 (forward flow). Recirculation ratio=1:1 to 4:1. Open surface, winter operation.

[a] Single-family home filters. [b] Restaurant (grease and oil inf/eff = 119/<1 mg/L respectively). [c] Small community treating average 15,000 gpd of septic tank effluent. [d] 1 gpd/ft^2 = 4 cm/day = 0.04m^3/m^2×day. [e] 1 lb BOD/1000ft^2×day = 0.00455 kg/m^2×day