National Small Flows Clearinghouse

Intermittent Sand Filters

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Fact Sheet

Introduction

Sand filter systems have been used for wastewater treatment in the U.S. since the late 1800s. In 1876, the community of Lenox, Massachusetts, built a sand filter system, and by 1893, six other communities were using sand filters for wastewater treatment. During this same time period, Sir Edward Frankland of England was documenting his work with natural sand beds.

An assessment conducted in 1985 by the U.S. Environmental Protection Agency of intermittent sand filter (ISF) systems revealed that sand filters are a low-cost, mechanically simple alternative. More recently, sand filter systems have been serving subdivisions, mobile home parks, rural schools, small communities, and other generators of small wastewater flows.

Sand filters are a viable addition/alternative to conventional methods when site conditions are not conducive for proper treatment and disposal of wastewater through percolative beds/trenches. Sand filters can be used on sites that have shallow soil cover, inadequate permeability, high groundwater, and limited land area.

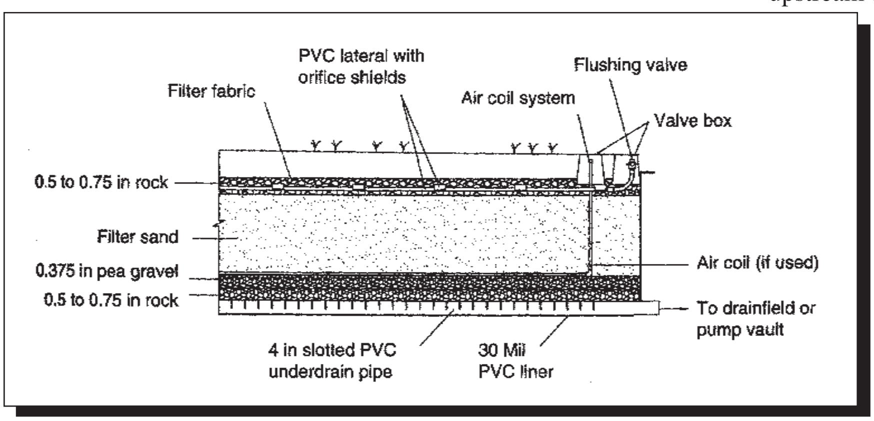

Figure 1: Typical Cross Section of an Intermittent Sand Filter

Source: Orenco Systems, Inc., Sutherlin, Oregon (1998), used with permission

Process Description

ISFs have 24-inch deep filter beds of carefully graded media. Sand is a commonly used media, but anthracite, mineral tailings, bottom ash, etc., have also been used. The surface of the bed is intermittently dosed with effluent that percolates in a single pass through the sand to the bottom of the filter. After being collected in the underdrain, the treated effluent is transported to a line for further treatment or disposal. The two basic components of an ISF system are a primary treatment unit(s) (a septic tank or other sedimentation system) and a sand filter. Figure 1 shows a schematic of a typical ISF.

ISFs remove contaminants in wastewater through physical, chemical, and biological treatment processes. Although the physical and chemical processes play an important role in the removal of many particles, the biological processes play the most important role in sand filters.

ISFs are typically built below grade in excavations 3 to 4 feet deep and lined with an impermeable membrane where required. The underdrain is surrounded by a layer of graded gravel and crushed rock with the upstream end brought to the surface and vented. Pea gravel is then placed on top of the graded gravel, and then sand is laid over top of the pea gravel. Another layer of graded gravel is laid down, with the distribution pipes running through it. A flushing valve is located at the end of each distribution lateral. Lightweight filter fabric is placed over the final course of rock to keep silt from moving into the sand while allowing air and water to pass through. The top of the filter is then backfilled with loamy sand that may be planted with grass. Buried ISFs are usually designed for single homes. Listed below are some common types of these sand filters.

Gravity Discharge ISFs

One variety of buried ISFs, the gravity discharge ISF, is usually located on a hillside with the long axis perpendicular to the slope to minimize the excavation required. Because the effluent leaving the sand filter flows out by gravity, the bottom of the sand

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filter must be several feet higher than the drainfield area. To achieve that difference in elevations, a sand filter may be constructed partially above ground.

Pumped Discharge ISFs

Another type of buried sand filter, the pumped discharge sand filter, is usually sited on level ground, but its location in relation to the drainfield is not critical since a pump located within the sand filter bed allows effluent to be pumped to a drainfield at any location or elevation. Discharge piping goes over—not through—the sand filter liner, so the integrity of the liner is protected.

Bottomless ISFs

A third type of buried sand filter has no impermeable liner and does not discharge to a drainfield, but rather directly to the soil below the sand.

Table 1 shows the typical design values for ISFs. These values are based on past experience and current practices and are not necessarily optimum values for a given application.

Advantages and Disadvantages

Some advantages and disadvantages of ISFs are listed below:

Advantages

- ISFs produce a high quality effluent that can be used for drip irrigation or can be surface discharged after disinfection.
- Drainfields can be small and shallow.
- ISFs have low energy requirements.
- ISFs are easily accessible for monitoring and do not require skilled personnel to operate.
- No chemicals are required.
- If sand is not feasible, other suitable media could be substituted that may be found locally.
- Construction costs for ISFs are moderately low, and the labor is mostly manual.
- The treatment capacity can be expanded through modular design.
- ISFs can be installed to blend into the surrounding landscape.
- The soil cover prevents odors.

Disadvantages

- The land area required may be a limiting factor.
- Regular (but minimal) maintenance is required.
- Odor problems could result from open filter configurations and may require buffer zones from inhabited areas.
- If appropriate filter media are not available locally, costs could be higher.
- Clogging of the filter media is possible.
- ISFs could be sensitive to extremely cold temperatures.
- ISFs may require an NPDES Permit when the effluent is surface discharged.

Performance

Sand filters produce a high quality effluent with typical concentrations of 5 mg/L or less of biochemical oxygen demand (BOD) and suspended solids (SS), as well as nitrification of 80% or more of the applied ammonia. Phosphorus removals are limited, but significant fecal coliform bacteria reductions can be achieved.

Table 1: Typical Design Criteria for ISFs

Item	Design Criteria
Pretreatment	Minimum level: septic tank or equivalent
Filter medium	
Material	Washed durable granular material
Effective size	0.25–0.75 mm
Uniformity coefficient	<4.0
Depth	18 to 36 in.
Underdrains	
Type	Slotted or perforated pipe
Slope	0–0.1%
Size	3–4 in.
Hydraulic loading	2–5 gal/ft^2·day
Organic loading	0.0005–0.002 lb/ft^2·day
Pressure distribution	
Pipe size	1–2 in.
Orifice size	1/8–1/4 in.
Head on orifice	3–6 ft.
Lateral spacing	1–4 ft.
Orifice spacing	1–4 ft.
Dosing	
Frequency	12–48 times/day
Volume/orifice	0.15–0.30 gal/orifice·dose
Dosing tank volume	0.5–1.5 flow/day

Adapted from: U.S. Environmental Protection Agency (1980); Crites and Tchobanoglous (1998) with permission

The performance of an ISF depends on the type and biodegradability of the wastewater, the environmental factors within the filter, and the design characteristics of the filter. The most important environmental factors that determine the effectiveness of treatment are media reaeration and temperature. Reaeration makes oxygen available for the aerobic decomposition of the wastewater. Temperature directly affects the rate of microbial growth, chemical reactions, and other factors that contribute to the stabilization of wastewater within the ISF. Filter performance is usually better in warmer climates than in colder ones.

Discussed below are several process design parameters that affect the operation and performance of ISFs.

The Degree of Pretreatment

An adequately sized, structurally sound, watertight septic tank will ensure adequate pretreatment of typical domestic wastewater.

Media Size

The effectiveness of a granular material as filter media is dependent on the size, uniformity, and composition of the grains. The size of the granular media correlates with the surface area available to support the microorganisms that treat the wastewater and consequently affects the quality of the filtered effluent.

Media Depth

Adequate sand depth must be maintained so that the zone of capillarity does not infringe on the upper zone required for treatment.

Hydraulic Loading Rate

In general, the higher the hydraulic load, the lower the effluent quality for a given media. High hydraulic loading rates

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are typically used for filters with a larger media size or systems that receive higher quality wastewater.

Organic Loading Rate

The application of organic material in the filter bed is a factor that affects the performance of ISFs. Hydraulic loading rates should be set to accommodate the varying organic load that can be expected in the applied wastewater. As with hydraulic loading, an increase in the organic loading rate results in reduced effluent quality.

Dosing Techniques and Frequency

It is essential that a dosing system provide uniform distribution (time and volume) of wastewater across the filter. The system must also allow sufficient time between doses for reaeration of the pore space. Reliable dosing is achieved by pressure-dosed manifold distribution systems.

Operation and Maintenance

The daily operation and maintenance (O&M) of large filter systems is generally minimal when properly sized. Buried sand filters used for residential application can perform for extended periods of time.

Primary O&M tasks require minimal time and include monitoring the influent and effluent, inspecting the dosing equipment, maintaining the filter surface, checking the discharge head on the orifices, and flushing the distribution manifold annually. In addition, the pumps should be installed with quick disconnect couplings for easy removal. The septic tank should be checked for sludge and scum buildup and pumped as needed. Table 2 below lists the typical O&M tasks for ISFs.

Table 2: Recommended O&M for ISFs

Item	O&M Requirement
Pretreatment	Depends on process; remove solids from septic tank or other pretreatment unit.
Dosing chamber	
Pumps and controls	Check every 3 months.
Timer sequence	Check and adjust every 3 months.
Appurtenances	Check every 3 months.
Filter media	
Raking	As needed.
Replacement	Skim sand when heavy incrustations occur; replace sand to maintain design depth.
Other	Weed as needed.
	Monitor/calibrate distribution device as needed.
	Prevent ice sheeting.

Source: U.S. Environmental Protection Agency (1980)

In extremely cold temperatures, adequate precautions must be taken to prevent freezing of the filter system by using removable covers.

Application

Placer County, California

Placer County, California, in the last 20 years has had to develop their land with onsite systems due to the popularity of their rural homes at elevations of 100 to 4,000 feet. The county extends along the western slope of the Sierra Nevada Mountains from Lake Tahoe through the foothills and into the Great Central Valley. Large areas of the county have marginal soil quality, shallow soil depth, and shallow perched groundwater levels.

In 1990, a program was initiated to permit the use of the Oregon-type ISF systems on an experimental basis to evaluate their performance and other related factors.

The ISF systems used in this study had the following components: a conventional septic tank followed by a separate pump vault; a plywood structure with a 30 mil PVC liner for the filter and appurtenances; carefully graded and clean sand 24 inches deep; a gravel over-layer and under-layer containing the pressurized piping manifold to distribute the septic tank effluent over the bed; and a collection manifold to collect the wastewater. The dimensions of the filter (for both three- and four- bedroom homes) was 19 feet x 19 feet at a design loading rate of 1.23 gal/ft^2/day. Summarized below in Table 3 are the results obtained from 30 ISF systems serving single-family homes during warm and cold weather.

Table 3: Comparison of Effluents from Single-Family Residential Septic Tanks and ISFs for 30 Systems in Placer County

Effluent Characteristic	Septic Tank Effluent	ISF Effluent	% Change
$CBOD_5$	160.2 (15)*	2.17 (44)*	98
TSS	72.9 (15)*	16.2 (44)*	78
NO_3-N	<0.1 (15)*	31.1 (44)*	99
NH_3-N	47.8 (15)*	4.6 (44)*	90
TKN	61.8 (15)*	5.9 (44)*	90
TN	61.8 (15)*	37.4 (44)*	40
TC	6.82×10^5 (13)*	7.30×10^2 (45)*	99 (3 logs)
FC	1.14×10^5 (13)*	1.11×10^2 (43)*	99 (3 logs)
Number of systems sampled	15	30	

*Number of samples

$CBOD_5$, TSS, and nitrogen expressed as mg/L; arithmetic mean. Fecal and total coliform expressed as geometric mean of MPN/100 mL.

Source: Cagle and Johnson (1994), used with permission from the American Society of Agricultural Engineers

The results of this study indicate that ISF systems showed a marked improvement in their effluent quality over septic tanks. Although the systems performed well, nitrogen and bacteria were not totally removed, which indicates that ISF systems should be used only where soil types and separations from the groundwater are adequate. Other findings were that early involvement of stakeholders is vital to the program's success; that effective system maintenance is essential; and that the local learning curve allows errors that adversely affect system performance.

Boone County, Missouri

A pressure-dosed ISF was installed and monitored on the site of a three-bedroom single-family residence in Boone County, Missouri. The sand filter, followed by a shallow drainfield, replaced a lagoon and was installed to serve as a demonstration

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site for the county. The soil condition at this site is normally acceptable for septic tank effluent, but the top 30 to 35 cm had been removed to construct the original sewage lagoon.

The existing septic tank was found to be acceptable and was retrofitted with a pump vault and a high-head submersible pump for pressure dosing the sand filter. The sand filter effluent drained into the pump vault in the center of the sand filter, which then pressure dosed two shallow soil trenches constructed with chambers. The system was installed in October 1995, and the performance was monitored for 15 months.

The sand filter used in this study consistently produced a high quality effluent with low BOD, SS, and ammonia nitrogen (NH_4-N). Table 4 below lists the various parameters studied. The aerobic environment in the sand filter is evident from the conversion rate of NH_4-N to nitrate nitrogen (NO_3-N) that also resulted in no odor problems. The fecal coliform numbers were consistently reduced by four log units.

Table 4: Effluent Characteristics of the ISF

Parameter	*Septic Tank*	*Sand Filter*	*% Change*
BOD (mg/L)	297	3	99.0
TSS (mg/L)	44	3	93.2
NH_4-N (mg/L)	37	0.48	98.7
NO_3-N (mg/L)	0.07	27	38,471
Fecal coliform (#/100 mL)	4.56E+05	7.28E+01	99.9

Source: Sievers (1998), used with permission from the American Society of Agricultural Engineers

The average electricity use by this system was 9.4 kWh/month, and the cost of operating two pumps in the system has been less than 70 cents per month. The high quality effluent produced by the sand filter also reduced the size of the absorption area.

Cost

Table 5 shows costs for single-pass sand filters used for a single-family residence (10 feet x 36 feet). For a single-family home, the main construction costs, primarily for labor and materials, generally run from $7,000 to $10,000 where installers have experience with sand filters. It should be noted, however, that these are typical costs, and actual costs will vary from site to site.

The cost of an ISF system depends on the labor, materials, site, capacity of the system, and characteristics of the wastewater. The main factors that determine construction costs are land and media, which are very site-specific.

Energy costs are mostly associated with the pumping of wastewater onto the filter. The energy costs typically range between 3 to 6 cents per day. Consequently, the energy costs of sand filters are lower than most small community wastewater processes, except for lagoons.

Table 5: Cost Estimate for Single-Family Residence

Item	Cost ($)
Capital Costs	
Construction costs	
1,500-gallon single compartment septic/pump tank @ 57cents/gallon	850
ISF complete equipment package (includes dual simplex panel, pump pkg., tank risers, lids, liner, lateral kit, orifice shields, etc.)	3,200
Installation (includes excavation and media costs)	3,000
Non-component costs	750
Engineering (includes soils evaluation, siting, design submittal, and construction inspections)	2,000
Contingencies (includes permit fees)	1,000
Land	May vary
Total Capital Costs	10,800
Annual O&M Costs	
Labor @ $65/hr. (2 hrs./yr.)	130/yr.
Power @ 10 cents/kWh	May vary
Sludge disposal	* 25/yr.

*Septic tank pumping interval based on 7 years with five occupants

Data supplied by Orenco Systems, Inc., Sutherlin, Oregon (1998)

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For more information on intermittent sand filters contact the NESC at (304) 293-4191.