# Recirculating Sand Filters

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Fact Sheet

## Introduction

The recirculating sand filter (RSF) concept was introduced in the late 1960s and early 1970s by Hines and Favreau, public health engineers from Illinois who were experimenting with sand filter designs. An RSF system is a modified version of the old-fashioned, single-pass open sand filter. It was designed to alleviate the odor problems associated with open sand filters. The noxious odors were eliminated through recirculation, which increases the oxygen content in the effluent that is distributed on the filter bed.

RSFs are a viable addition/alternative to conventional methods of treatment when soil conditions are not conducive to 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. RSF systems commonly serve subdivisions, mobile home parks, rural schools, small municipalities, and other generators of small wastewater flows.

Since 1970, this technology has evolved significantly in the areas of equipment, configuration, and dosing rates.

The three basic components of an RSF system are a pretreatment unit, a recirculation tank, and an open sand filter. (See Figure 1.)

Wastewater first flows into a septic tank (or in the case of a clustered or community system, a number of septic tanks) for primary treatment. A standard concrete or fiberglass septic tank can be used, with size being relative to the home/facility served.

The partially clarified effluent from the pretreatment tank then flows into a recirculation tank. The volume of the recirculation tank should be equivalent to at least 1 day's raw wastewater flow (or follow local jurisdiction requirements). In the recirculation tank, raw effluent from the septic tank and the sand filter filtrate are mixed and pumped back to the sand filter bed.

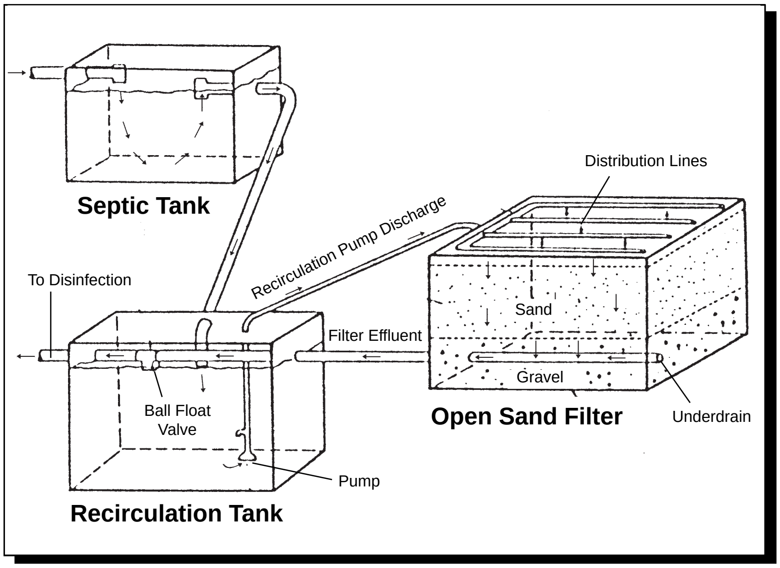


**Figure 1: Typical Recirculating Sand Filter System**

*Adapted from: Hines and Favreau (1974) with permission*

## Process Description

Sand filters remove contaminants in wastewater through physical, chemical, and biological 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.

The RSF is an open sand filter with a sand media depth of 2 feet. A layer of graded gravel (about 12 inches) is provided under the sand for support to the media and to surround the underdrain system. A portion of the mixture (septic tank effluent and sand filtrate) is dosed by a submersible pump through a distribution system that applies it

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evenly over the sand filter. The dosing frequency is controlled by a programmable timer in the control panels.

The filtrate from the sand filter is collected by underdrains that are located at the bottom of the bed. The filter discharge line passing through the recirculation tank is located near the top of the tank.

Figure 1 on page 1 shows a ball float valve connected to a downturned "T" on the discharge line, in which is housed a rubber ball with a diameter slightly larger than that of the pipe. As the filter effluent rises in the tank, it forces the rubber ball tight against the bottom of the downturned leg, thus discharging the effluent for further treatment or disposal. Other control mechanisms may be used, but care must be taken to ensure that the recirculation tank does not run dry.

Table 1 gives typical design specifications for RSFs.

## Advantages and Disadvantages

Some advantages and disadvantages of RSFs are listed below:

### *Advantages*

- RSFs provide a very good effluent quality with over 95% removal of biochemical oxygen demand (BOD) and total suspended solids (TSS).
- The treatment capacity can be expanded through modular design.
- RSFs are effective in applications with high levels of BOD.
- RSFs are easily accessible for monitoring and do not require a lot of skill to maintain.
- A significant reduction in the nitrogen level is achieved.
- If sand is not feasible, other suitable media could be substituted that may be found locally.
- No chemicals are required.
- Less land area is required (1/5 of the land area of a single-pass sand filter) for RSFs than for single-pass sand filters.

### *Disadvantages*

- If appropriate media are not available locally, costs could be higher.
- Weekly maintenance is required for the media, pumps, and controls.
- Design must address extremely cold temperatures.

## Performance

RSFs produce a high quality effluent with approximately 85 to 95% BOD and TSS removal. In addition, almost complete nitrification is achieved. Denitrification has been shown to occur in RSFs. Depending on modifications in design and operation, 50% or more of applied nitrogen can be removed.

The performance of an RSF depends on the type and biodegradability of the wastewater, the environmental conditions within the filter, and the design characteristics of the filter. Temperature affects the rate of microbial growth, chemical reactions, and other factors that affect the stabilization of wastewater within the RSF.

Although physical and chemical processes play an important role in the removal of many particles, the biological processes play the most important role since bacteria are the primary workers in sand filters.

**Table 1: Typical Design Criteria for RSFs**

| *Item* | *Design Criteria* |
|---|---|
| Pretreatment | Minimum level: septic tank or equivalent |
| Filter medium | |
| Material | Washed durable granular material |
| Effective size | 1.0 to 3.0 mm |
| Uniformity coefficient | <4.0 |
| Depth | 24 in. |
| Underdrains | |
| Type | Slotted or perforated pipe |
| Slope | 0–0.1% |
| Bedding | Washed durable gravel or crushed stone (0.25–1.50 in.) |
| Hydraulic loading | 3.0 to 5.0 gpd/ft$^2$/ (forward flow) |
| Organic loading | 0.002–0.008 lb/ft$^2$·day |
| Recirculation ratio | 3:1 to 5:1 |
| Recirculation tank | Volume equivalent to at least 1 day's raw wastewater flow |
| Distribution and dosing system | Pressure-dosed manifold distribution system and spray nozzles where permitted |
| Dosing | |
| Time on | <2–3 minutes |
| Time off | Varies |
| Frequency | 48–120 times/day or more |
| Volume/orifice | 1–2 gal/orifice·dose |

*Adapted from: Crites and Tchobanoglous (1998) with permission from The McGraw-Hill Companies*

Other parameters that affect the performance and design of RSFs are the degree of wastewater pretreatment, the media size, media depth, hydraulic loading rate, organic loading rate, and dosing techniques and frequency.

The effectiveness of a granular material as filter media is dependent on the size and uniformity of the grains. The size of the granular media affects how much wastewater is filtered, the rate of filtration, the penetration depth of particulate matter, and the quality of the filter effluent.

High hydraulic loading rates are typically used for filters that receive higher quality wastewater. The accumulation of organic material in the filter bed is another factor that affects the performance of RSFs. As with hydraulic loading, an increase in the organic loading rate results in shorter filter life.

## Operation and Maintenance

RSFs require routine maintenance, although the complexity of maintenance is generally minimal. Primary O&M tasks 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. The surface of the sand bed should be kept weed free.

In addition, the septic tank should be checked for sludge and scum buildup and pumped as needed. The recirculation tank should also be inspected and maintained as necessary.

The pumps should be installed with quick disconnect couplings for easy removal. A duplicate recirculation pump

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should be available for backup. Table 2 lists the typical O&M tasks for RSFs.

**Table 2: Recommended O&M for RSFs**

| *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 | If continuous hydraulic or biological overloading occurs, the top portion of the media can clog and may need to be replaced if not corrected in time. |
| Other | Weed as needed.<br>Monitor/calibrate distribution device as needed.<br>Prevent ice sheeting. |

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

In very cold climates, RSF design must include elements that prevent freezing of standing water. Distribution lines must drain between doses and tanks, and the filter should be insulated.

## Application

### *Stonehurst Development in Martinez, California*

The Stonehurst development is a small residential subdivision near the city of Martinez in Contra Costa County, California. This subdivision is located in a hilly, rural area that did not have a wastewater collection system. Thus, an innovative decentralized wastewater system was designed to provide for wastewater collection, treatment, disinfection, and reuse.

The innovative system combines the use of septic tanks, screened effluent filter vaults, high-head effluent pumps, small-diameter variable grade sewers, pressure sewers, a recirculating granular medium filter, an ultraviolet (UV) disinfection unit, a subsurface drip irrigation system for wastewater reuse, and a community soil absorption field for wintertime disposal. The principal elements for treatment consisted of two sections of recirculating granular filter followed by disinfection.

Each filter was 24 inches deep with 3 mm gravel (washed and rounded with less than 2% fines) sandwiched between layers of drain rock, which was coarse, washed gravel approximately 1 to 2.5 inches in diameter. The wastewater was pumped from the recirculating tank to the filters for 5 minutes every half hour, and circulated approximately five times through the filter. Since one half of the filter was used during the time the study was conducted, the hydraulic loading was 1.2 gal/ft$^2$.

Performance data were calculated for the 28-month period from June 1994 through September 1996, based on an average of at least two samples per month for 5-day BOD, and at least four samples per month for TSS, chemical oxygen demand (COD), pH, and total coliform. Summarized in Table 3 are the performance data of effluent samples that had passed through the recirculating gravel filter and the UV system.

**Table 3: Performance Data for Stonehurst Wastewater Treatment System**

| *Constituent** | *Range* |
|---|---|
| $BOD_5$ | 0– <5 mg/L |
| COD | 1–18 mg/L |
| TSS | 2–15 mg/L |
| pH | 6.96–8.65 unitless |
| Total coliform | <2–12.5 MPN/100 mL |
| $NH_4$ | 0–15 mg/L |
| $NO_3$ | 3.55–37 mg/L |
| TKN | 0–3 mg/L |
| Oil and grease | 0–12 mg/L |
| TDS | 340–770 mg/L |
| EC | 433–1,200 µmhos/cm |

*TDS = total dissolved solids, EC = electrical conductivity, µmhos/cm = micro mhos per centimeter

*Source: Crites et al. (1997)*

To date, the Stonehurst decentralized wastewater system has exceeded all expectations by performing beyond required standards.

### *Elkton, Oregon*

An RSF was installed and monitored for a community in Elkton, which is located on the Umpqua River in Southwestern Oregon. The population of this community was 350, mostly residential with some commercial establishments. The wastewater generated from stores, restaurants, schools, and about 100 residences was first pretreated and screened in individual septic tanks. Partially clarified effluent was then collected and conveyed by an effluent pressure sewer system to an RSF and finally pumped to a drainfield for final treatment and disposal.

The sand filter was 60 feet x 120 feet with four cells, 36 inches deep, and designed to treat 30,000 gallons per day (gpd). A recirculation tank of 29,500-gallon capacity was used with four one-horsepower pumps. Each pump dosed one cell at the rate of 130 gallons per minute. Two pumps alternately dosed during each cycle. The actual recirculation ratio was 3.2:1, and during low periods, a motorized valve allowed 100% recirculation.

Effluent quality data obtained between February 1990 through October 1997 are presented in Table 4 below:

**Table 4: Elkton's RSF Effluent Quality Data**

| *Wastewater Characteristics* | *Influent (mg/L)* | *Effluent (mg/L)* |
|---|---|---|
| BOD | 123 | 4 |
| TSS | 37 | 9 |
| $NH_3$-N | 51 | 10 |
| $NO_3$-N | 2 | 26 |

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

It was concluded from this study that the RSF produced a high quality effluent, thus protecting the river nearby at an affordable cost. Capital costs for RSFs range from $3 to $10 per treated gallon. The annual operating costs are very low. For example, at Elkton, the annual O&M cost for the RSF is less than $5,000, which includes $780 for electricity.

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Use of a smaller, effectively sized media (<3.0 mm) would have resulted in better nitrification, but this was not a concern when the design was made.

## Cost

The cost of RSFs depends on the labor, materials, site, capacity of the system, and characteristics of the wastewater. One of the most significant factors that affects the cost of sand filters is media cost. Therefore, using locally available materials for the media is usually the most cost-effective option.

Table 5 below shows the costs for RSFs with sand media and black beauty sand media used in a facility treating 5,000 gpd. It should be noted, however, that these are typical costs, and actual costs will vary from site to site and among different designs. Local regulatory requirements and labor rates will affect costs as well.

The cost of the pretreatment unit(s) for an RSF system will depend on the waste stream characteristics specific to the site application. Effluent sewer systems incorporate individual or community septic tanks to pretreat wastewater before it flows into the recirculation tank. Developments that include commercial establishments may require higher levels of pretreatment in the form additional septic tank storage, surge capacity, grease traps, and possibly aerobic digestion.

Suggested maintenance for RSFs range from weekly inspections (15 to 30 minutes) to monthly inspections for approximately 1 hour.

**Table 5: Cost Estimates for a 5,000 gpd Facility Using Two Different Media**

| *Item* | *Cost ($)* | |
|---|---|---|
| | *[1]Sand* | *[2]Black Beauty Sand* |
| Capital Costs | | |
| Construction costs | | |
| Pretreatment | May vary | May vary |
| Recirculation tank and pumping system | 10,000 | 9,000 |
| Sand filter | 10,000 [a] | 43,100 |
| Non-component costs | May vary | May vary |
| Engineering | 3,000 | 7,800 |
| Contingencies | 3,000 | 7,800 |
| Land | May vary | May vary |
| **Total Capital Costs** | **26,000** | **67,700** |
| Annual O&M Costs | | |
| Labor | 20/hr. | 20/hr. |
| Power | May vary | May vary |
| Sludge disposal @ 10 cents/gal. | 50/yr. [b] | 50/yr. [b] |

Note: Non-component costs include piping and electrical. Engineering and contingency each equal approximately 15% of construction costs. Costs toward land, labor, and power may be different from site to site and system to system.

[a]Design does not include precast concrete cells.

[b]Average pumping frequency is every 5 years.

*Data supplied by [1]Orenco Systems, Inc., Sutherlin, Oregon (1998) and [2]Ashco-A-Corporation, Morgantown, West Virginia (1998)*

The Ashco Rock Filter Storage II (RFSII) sand filters consist of three different gradations of media, including high spec black beauty sand, Ashco's Bottom Zone, and spray grids with spray nozzles to distribute the recycled filtrate evenly over the media, all contained in 75 square foot precast concrete cells. It should be noted that the costs appearing in Table 5 for sand filters include the labor and machinery necessary to install media, plumbing, and tankage in the excavation and landscape, the same should be noted for the recirculation tank (minus the media).

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*For more information on recirculating sand filters or a list of other fact sheets, contact the NSFC at West Virginia University, P.O. Box 6064, Morgantown, WV 26506-6064. Phone: (800) 624-8301 or (304) 293-4191. Fax: (304) 293-3161. World Wide Web site:* http://www.nsfc.wvu.edu.

*The NSFC provides free and low-cost informational services and products to help homeowners and small communities address their wastewater needs. Also, information about manufacturers, consultants, regulations, and facilities can be obtained from the NSFC's databases.*