Tech Brief

A NATIONAL DRINKING WATER CLEARINGHOUSE FACT SHEET

Slow Sand Filtration

Summary

First used in the U.S. in 1872, slow sand filters are the oldest type of municipal water filtration. Today, they remain a promising filtration method for small systems with low turbidity or algae-containing source waters. Slow sand filtration does not require pretreatment or extensive operator control—which can be important for a small system operator with several responsibilities.

What is slow sand filtration?

Slow sand filtration is a simple and reliable process. They are relatively inexpensive to build, but do require highly skilled operators.

The process percolates untreated water slowly through a bed of porous sand, with the influent water introduced over the surface of the filter, and then drained from the bottom.

Properly constructed, the filter consists of a tank, a bed of fine sand, a layer of gravel to support the sand, a system of underdrains to collect the filtered water, and a flow regulator to control the filtration rate. No chemicals are added to aid the filtration process.

Advantages

Design and operation simplicity—as well as minimal power and chemical requirements—make the slow sand filter an appropriate technique for removing suspended organic and inorganic matter. These filters also may remove pathogenic organisms.

Slow sand filtration reduces bacteria, cloudiness, and organic levels—thus reducing the need for disinfection and, consequently, the presence of disinfection byproducts in the finished water. Other advantages include:

- Sludge handling problems are minimal.
- Close operator supervision is not necessary.
- Systems can make use of locally available materials and labor.

Slow Sand Filter

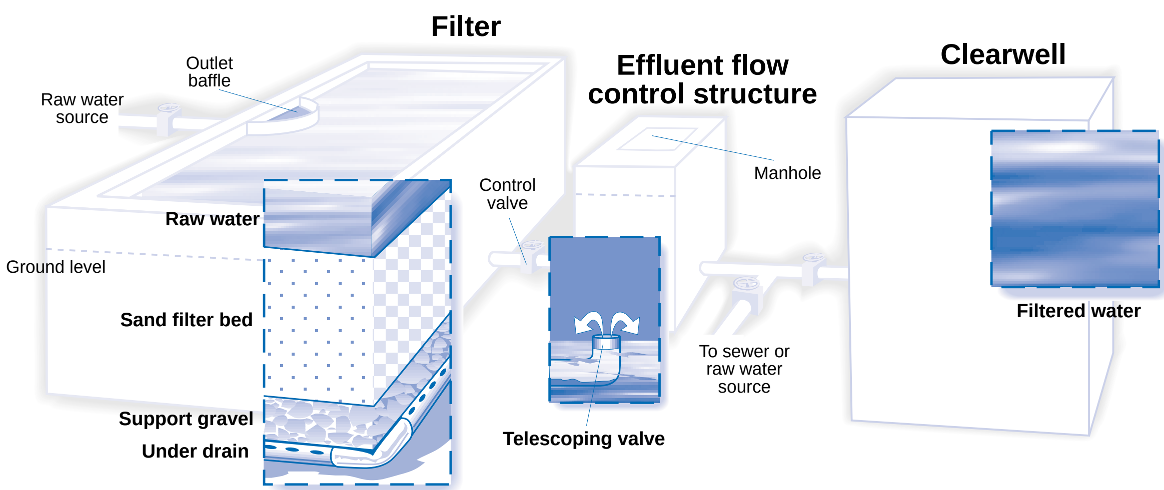

TABLE 1

Typical Treatment Performance of Conventional Slow Sand Filters

Water Quality Paramenter	Removal Capacity
Turbidity	<1.0 NTU
Coliforms	1-3 log units
Enteric Viruses	2-4 log units
Giardia Cysts	2-4+log units
Cryptosporidium Oocysts	>4 log units
Dissolved Organic Carbon	<15-25%
Biodegradable Dissolved Organic Carbon	<50%
Trihalomethane Precursors	<20-30%
Heavy Metals	
Zn, Cu, Cd, Pb	>95-99%
Fe, Mn	>67%
As	<47%

Source: Adapted from Collins, M.R. 1998.

Slow sand filters also provide excellent treated-water quality. (See Table 1.) Slow sand filters consistently demonstrate their effectiveness in removing suspended particles with effluent turbidities below 1.0 nephelometric turbidity units (NTU), achieving 90 to 99 + percent reductions in bacteria and viruses, and providing virtually complete *Giardia lamblia* cyst and *Cryptosporidium* oocyst removal.

Limitations

Slow sand filters do have certain limitations. They require a large land area, large quantities of filter media, and manual labor for cleaning.

Water with high turbidity levels can quickly clog the fine sand in these filters. Water is applied to slow sand filters without any pretreatment when it has turbidity levels lower than 10 NTU.

When slow sand filters are used with surface waters that have widely varying turbidity levels, infiltration galleries or rough filters—such as up-flow gravel filters—may be used to reduce turbidity.

Waters with a very low nutrient content may impair turbidity removal since some nutrients must be present that promote biological ecosystem growth within the filter bed.

Slow sand filters do not completely remove all organic chemicals, dissolved inorganic substances, such as heavy metals, or trihalomethane (THM) precursors—chemical compounds that may form THMs when mixed with chlorine. Also, waters with very fine clays are not easily treated using slow sand filters.

A granular activated carbon (GAC) sandwich filter is a modified slow sand filter that removes organic material. This filter uses a base sand layer that is approximately 1 foot deep, an intermediate GAC layer approximately 0.5 feet, and a top sand layer approximately 1.5 feet deep. This modified slow sand filter effectively removes pesticides, total organic carbon, and THM precursors.

Slow sand filters are less effective at removing microorganisms from cold water because as temperatures decrease, the biological activity within the filter bed declines.

Process Description

Slow sand filters require a very low application or filtration rate (0.015 to 0.15 gallons per minute per square foot of bed area, depending on the gradation of the filter medium and the quality of the raw water). The removal action includes a biological process in addition to physical and chemical ones.

A sticky mat of biological matter, called a "schmutzdecke," forms on the sand surface, where particles are trapped and organic matter is biologically degraded. Slow sand filters rely on this cake filtration at the surface of the filter for particulate straining. As the surface cake develops during the filtration cycle, the cake assumes the dominant role in filtration rather than the granular media.

Pilot testing is always necessary when designing slow sand filters. Currently, engineers are not able to predict the performance of a slow sand filter with a specific quality of raw water. Operation of a small pilot filter, preferably over several seasons of the year, will insure adequate performance of the full-scale plant.

Remember, after the designer sets the parameters—such as the plant filtration rate, bed depth, and sand size—there is little a plant operator can do to improve the performance of a slow sand filter that does not produce satisfactory water.

Slow sand filter pilot plant testing does not have to be expensive. Pilot plant testing has been done using manhole segments and other prefabricated cylindrical products, such as filter vessels.

Slow sand filter pilot facilities operate over long periods of time—up to a year—but the level of effort can be quite low, consisting of daily checks of head loss, flow rate, water temperature, and turbidity and taking coliform samples.

Since the purification mechanism in a slow sand filter is essentially a biological process, its efficiency depends upon a balanced biological community in the schmutzdecke. Therefore, filters should operate at a constant rate. When operation is stopped, the microorganisms causing bacteriological degradation of trapped impurities lose their effectiveness. Intermittent operation disturbs the continuity needed for efficient biological activity.

Allowing the filter to operate at a declining rate is one way of overcoming this problem. Declining rate filtration produces additional water, which is generally satisfactory. Moreover, the declining-rate mode may be applied during overnight operation, resulting in significant labor savings.

Storing filtered water is essential at a slow sand filter plant for two reasons. First, because of the importance of establishing biological activity, using chlorine ahead of the filter is inappropriate, and the operator must provide disinfectant contact time in a storage basin. Second, storage is needed for production equalization and demand.

Monitoring and Operation Requirements

A slow sand filter must be cleaned when the fine sand becomes clogged, which is measured by the head loss. The length of time between cleanings can range from several weeks to a year, depending on the raw water quality. The operator cleans the filter by scraping off the top layer of the filter bed. A ripening period of one to two days is required for scraped sand to produce a functioning biological filter. The filtered water quality is poor during this time and should not be used.

In some small slow sand filters, geotextile filter material is placed in layers over the surface. In this cleaning method, the operator can remove a layer of filter cloth periodically so that the upper sand layer requires less frequent replacement.

In climates subject to below-freezing temperatures, slow sand filters usually must be housed. Uncovered filters operating in harsh climates develop an ice layer that prevents cleaning. Thus, they will operate effectively only if turbidity levels of the influent are low enough for the filter to operate through the winter months without cleaning. In warm climates, a cover over the slow sand filter may be needed to reduce algae growth within the filter.

Before cleaning a slow sand filter, the operator should remove floating matter, such as leaves and algae. When one unit is shut down for cleaning, the others are run at a slightly higher rate to maintain the plant output.

TABLE 2

Design Summary of a Slow Sand Filter

Design parameters	Recommended range of values
Filtration rate	$0.15\ m^3/m^2 \cdot h$ ($0.1–0.2\ m^3/m^2 \cdot h$)
Area per filter bed	Less than 200 m^2 (in small community water supplies to ease manual filter cleaning)
Number of filter beds	Minimum of two beds
Depth of filter bed	1 m (minmum of 0.7 m of sand depth)
Filter media	Effective size (ES) = 0.15–0.35 mm; uniformity coefficient (UC) = 2-3
Height of supernatant water	0.7–1 m (maximum 1.5 m)
Underdrain system	
Standard bricks	
Precast concrete slabs	Generally no need for further hydraulic calculations
Precast concrete blocks with holes on the top	
Porous concrete	
Perforated pipes (laterals and manifold type)	Maximum velocity in the manifolds and in laterals = .3 m/s Spacing between laterals = 1.5 m Spacing of holes in laterals = 0.15 m Size of holes in laterals =3 mm

Source: Vigneswaran, S. and C. Visvanathan. 1995

After cleaning, the unit is refilled with water through the underdrains. This water can be obtained from an overhead storage tank or by using water from an adjacent filter. When the clearwell is designed, the temporary reduction of plant output should be considered, ensuring that sufficient water is available for the users.

Once the filter is cleaned, the microorganisms usually re-establish and produce an acceptable effluent. In cooler areas, ripening may take a few days. Even then, if the effluent's turbidity is sufficiently low, the water supply can be resumed after one day with adequate chlorination.

Slow sand filter monitoring and operation is not complicated. Daily tasks include reading and recording head loss, raw and filtered water turbidity, flow rates, and disinfectant residual. If necessary, the operator should adjust the flow to bring water production in line with demand.

In addition, with the promulgation of the Surface Water Treatment Rule, each day the operator needs to use the flow data and disinfectant residual data to calculate contact time values and determine if disinfection is sufficiently rigorous. These duties may require one to two hours unless automated.

Where can I find more information?

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