Fact Sheet

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Slow Sand Filtration: Operation and Maintenance

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What Is Slow Sand Filtration?

Slow sand filtration (SSF) is a low-tech, cost-effective, and reliable water treatment system, which has been widely used since early 1800s and is still very common in small rural and remote communities. The US Environmental Protection Agency (1997) has identified SSF as the most suitable filtration technology for small systems when used with source water of appropriate quality.

SSF treatment can be used with or without pretreatment. The effectiveness of SSF depends on a number of factors, including source water properties, temperature, filter ripening, and maintenance. Without any pretreatment, SSF can efficiently treat water with low levels of turbidity (e.g. < 5 NTU) and natural organic matter (e.g. DOC < 2 mg/L) (US EPA, 1997). More importantly, SSF is also an efficient technique for the removal of pathogenic microorganisms including viruses, bacteria, and protozoan cysts and oocysts (Logsdon *et al*., 2002). The main reasons for high efficiency are the very slow filtration rate (ranged from 0.1 - 0.4 m/h) and the biological layer that accumulates within the top layer of the sand surface (i.e., *schmutzdecke* or biofilm).

Slow sand filters are typically designed with a bed of sands about 1 m in depth (minimum of 0.7 m of sand depth) with about 0.7 - 1 m of water on top of the bed (Ellis and Wood, 1985; Logsdon *et al*., 2002). The effective size of filter media ranges from 0.15 – 0.35 mm and the uniformity coefficient should be 2 – 3. A minimum of two beds is required, and the area per filter bed should be less than 200 m^2 in small communities to ease manual filter cleaning (Logsdon *et al*., 2002).

Slow Sand Filter & Pretreatment

Slow sand filtration plants generally are designed with no chemical pretreatment (e.g. coagulation); therefore source water must be of low turbidity (e.g., turbidity < 5 NTU for SSF with no roughing filter) (US EPA, 1997). To apply SSF in challenging source water conditions, some modifications may be needed to the traditional design (Gottinger *et al.*, 2011). For example, a roughing filter can be installed to treat water with high turbidity prior to the slow sand filter; ozone oxidation can be used to break down natural organic matter which is desirable for the biofilm growth. Granular activated carbon (GAC) can be used following ozonation, prior to the SSF to remove any residual ozone that might be detrimental to the microorganisms in the *schmutzdecke* or can be used as an additional barrier to adsorb organics after the SSF

Table 1. The Advantages and Limitations of Using Slow Sand Filters

Advantages	Limitations
• Simple design, operation, and maintenance requirements; • Minimal power and chemical requirements; • Low operational costs; • Minimal sludge handling problems; • Close operator supervision is not necessary; • Low operator skill level ; • Biological process removes pathogens and other contaminants.	• Requires large footprint; • Labor-intensive manual filter cleaning; • Use is limited to low turbidity water (unless additional processes are used) • The biological process can be impaired at low temperature, or low nutrient content; • Operation complexity increases when ozone pretreatment and/or GAC are included.

The benefit of using a roughing filter is to reduce the turbidity loading on the SSF, and therefore the slow sand filer run time can be improved. According to a study by Gottinger *et al.* (2011), roughing filters can handle source water turbidity in the range of 50 to 200 NTU. A roughing filter normally consists of three layers of gravel beds sized from coarsest to finest, where the first bed consists of the coarsest gravel and the last bed having the finest. Typical filtration rates for roughing filters are between 0.3 – 1.5 m/h (Bellamy *et al*., 1985).

Ozone pretreatment breaks down the large organic molecules into smaller ones, which are more readily biodegradable and can be used easily by microorganisms in the SSF to form the biofilm (Allen *et al.,* 1988). In addition, ozonation can improve the SSF performance in cold temperatures when the biological activity is slowed down.

GAC has also been used in modified SSF system to enhance the removal of organics. GAC can remove natural organic matter, cyanotoxins, taste and odour compounds, ozonation by-products. A GAC layer can be used in the roughing filter, on the top of the slow sand filter, or even beneath the sand layer (Haarhoff and Cleasby, 1991). This so-called GAC sandwich filter would be replaced when new sand needs to be added to the filter. A full-scale GAC sandwich filter was found to be able to remove 30 – 40% of influent total organic carbon, reduce pesticide concentrations from as high as 0.5 µg/L to below 0.1 µg/L (Logsdon *et al.,* 2002).

As a result of these modifications, SSF has evolved into a robust process that can be operated within a broad range of source water quality and operating conditions (Logsdon *et al.,* 2002). The advantages and limitations of using slow sand filters in small systems are compared in Table 1.

Operation & Maintenance

Maintenance of SSF is required to prevent the filter bed from becoming clogged when significant head loss occurs. During the maintenance, the SSF is drained and the top layer of sand is removed by scraping (1 – 3 cm). After several scrapings, the filter media may be reduced to its minimum bed depth and additional sand may be required with either new or cleaned filter media (Gottinger *et al*., 2011). However, this step is very time-consuming. It is estimated that 5 hours are required for the removal of each 100 m^2 surface area of filter (Pizzolatti *et al*., 2015). An alternative method of cleaning a SSF is to simply disturb the top layer of the filter using a garden rake while maintaining a flow of water across the surface of the filter. This water containing the debris is directed to waste.

Slow sand filters require sufficient time to ripen after the start-up or after the maintenance cleaning. SSF ripening is achieved by pumping raw water through the filters to waste until both biological and physical-chemical ripening occur. Physical-chemical ripening can be determined by monitoring the effluent turbidity and particle counts. Biological ripening is more important as a developed *Schmutzdecke* is required for fully efficient pathogen and organic carbon removal. Biological ripening may occur over several days or several months, depending on several factors including pH, temperature, available organic nutrients, filtration rate, and raw water quality (Logsdon *et al.,* 2002). However, the mechanisms of biological ripening are still poorly understood and the microbial communities associated with this process are not well studied.

Performance of SSF

SSF can remove pathogenic microorganisms effectively. According to Haig *et al.* (2011), SSF can provide over 3-log removals of *Cryptosporidium*, 1 to 3-log removals of enteric bacteria, 2 to 4-log removals of viruses, and *Giardia* cysts, depending on treatment conditions and influent microorganism density. However, the microbiological removal is affected by lower temperatures where the biological processes are slowed down (Hijnen et al., 2004).

According to the Procedure for Disinfection of Drinking Water in Ontario, SSF must be well maintained and operated to achieve at least 2-log *Giardia* cyst removal, 2-log *Cryptosporidium* oocyst removal and 2-log virus removal credits.

Depending on the source water condition and the design of SSF, the removal of organics varies. Dissolved organic carbon (DOC) removal in a range of 5 – 40% was reported in the literature (Haig *et al.,* 2011), but the removal of the biodegradable portion, biodegradable dissolved organic carbon (BDOC), was as high as 46 – 75%. In another study, up to 75% DOC removal by a SSF with no pretreatment was reported (Gottinger *et al*., 2011). Cold water temperature has shown a significant negative impact in the natural organic matter removal (Gottinger *et al*., 2011).

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