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Filtering Wastewater with Sand

Barb McCarthy, (Research Fellow),
Natural Resources Research Institute, University of Minnesota, Duluth.

This is the third in a series of articles on alternative wastewater treatment systems in Minnesota. Portions of this article were taken from the Summer 1997 issue of Pipeline, a publication of the National Small Flows Clearinghouse.

Sand filters have been used for over 100 years to treat wastewater. In fact, a mound is a sand filter built above the surface. Sand filters are reliable systems when properly designed, constructed, and maintained. They are typically constructed of beds of sand two to three feet deep. The filter material (called media) is contained in either a plastic liner or concrete tank. Depending on soil conditions, sand filters can be constructed above ground, partially above ground, or entirely below the surface.

Figure 1. Single-pass sand filters for two different homes on small lake lots: one system above the ground surface(using locking blocks) due to high ground water; the second system is below the surface in the grassy area (with well-drained soils) next to the garage.

Sand Filter Basics

There are a few basic design and operating principles common to every type of sand filter system. First, to prevent the filter from clogging, the wastewater must be pre-treated to remove solids and scum. Pre-treatment of household wastewater usually takes place in a watertight septic tank. Screens are typically used in the septic tank as an important step to ensure that no solids carry over into the sand filter.

After the solids have been removed, a pump regulated with a timer, doses wastewater to the sand filter in timed intervals. Wastewater applications are spaced intermittently to allow the filter media to drain between doses. This ensures that oxygen is introduced into the filter with each dose of wastewater. Oxygen is critical to the biological and chemical treatment processes that take place inside the filter. Treatment of the wastewater occurs as it slowly trickles through the sand. The wastewater treated by sand filtration is generally colorless and odorless. After passing through the sand media, the wastewater is collected in an underdrain where it flows to the soil for final polishing and subsurface dispersal.

It is important that the wastewater be distributed evenly over the filter surface, applied through a network of small distribution pipes at the top of the sand filter media. A geotextile fabric is then placed on top of the filter bed and covered with 9 to 12 inches of permeable backfill material. Typically, a grass cover is established by seeding or sodding.

Sand filters are constructed or assembled on-site by a licensed contractor. Most materials are available in Minnesota and suitable sand filter media can usually be purchased from local aggregate companies. The media must be clean (no small soil grains) to allow the wastewater to flow correctly through it. If not, smaller soil grains will settle in the spaces between larger grains, leaving no place for the wastewater to flow and hydraulic failure would occur.

Common Sand Filter Designs

There are several possible sand filter system designs. The two most common types of sand filters are the single-pass and re-circulating. In a single-pass sand filter, wastewater passes through the sand filter just once. In a re-circulating sand filter, wastewater passes through the sand filter several times before dispersed into the natural soil.

Single-Pass Sand Filters

Single-pass sand filters are the most common filters used for homes, small businesses, and other small flows. These filters are constructed on-site and usually require an excavation three to five feet deep. The filter must be placed in a location to avoid contact with groundwater and surface water runoff.

The sand filter unit may be contained in an impermeable liner, as shown in Figure 2, or in a concrete tank. Underdrain pipes and a graded layer of washed gravel are placed at the bottom of the filter bed, with the finer gravel on top of the coarser gravel to keep the sand grains from washing into the underdrain system.

Figure 2. A single-pass sand filter being constructed at NERCC showing the top of the media before completion of the distribution network and final cover.

The sand filter media is then placed on top of the layer of fine gravel. As with all sand filters, the depth of the media depends on the size of the grains and other factors, but normally ranges from 24 to 36 inches. Another graded layer of gravel is placed on top of the sand that surrounds the network of distribution pipes. These pipes spread wastewater at the top of the sand media.

Most single-pass sand filters are dosed numerous times per day and are designed to receive hydraulic loads of 1.0 to 1.5 gallons per square foot per day. The best performance is generally achieved when wastewater is dosed to a sand filter frequently (hourly) with a small volume of wastewater. After wastewater passes through the sand filter, it collects in an underdrain network and is conveyed to the soil for final polishing and subsurface dispersal.

Figure 3. Installation of the pressure distribution network and the completed sand filters covered with wood chips at NERCC.

The final sand filter effluent is of high quality, with five-day Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) less than 10 milligrams per liter. Both BOD_5 and TSS are indicators used to assess treatment and its potential impact on the environment. Sand filters also remove many pathogens, such as viruses and harmful bacteria, but we rely on the natural soil to remove the remaining pathogens in on-site sewage treatment systems.

Recirculating Sand Filters

In a recirculating sand filter, wastewater flows by gravity from a septic tank to a recirculation tank, which is equipped with a pump, a timer, and floats. Wastewater is pumped to the filter when it reaches a certain level in the tank or in timed doses (ie.: hourly).

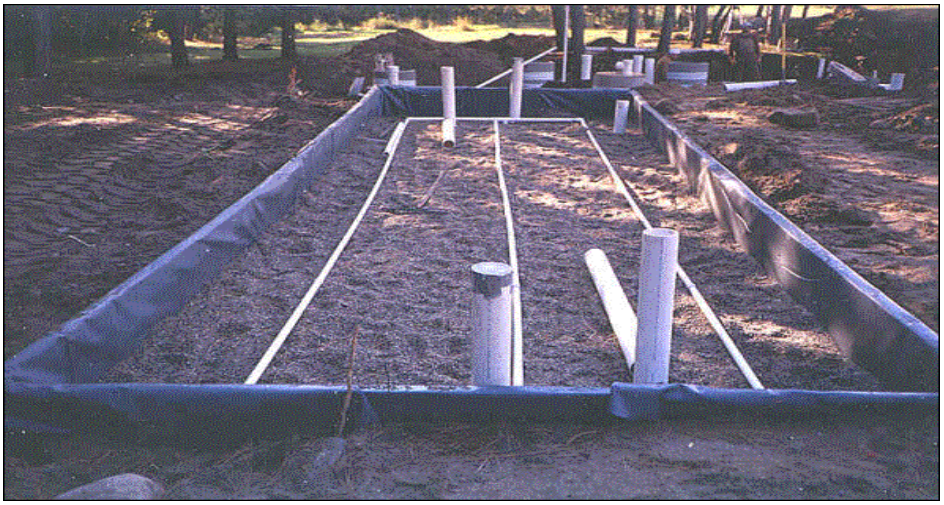

Figure 4. Construction of a recirculating sand filter at the Iron Range Resources and Rehabilitation Board (IRRRB) office building in Eveleth showing the pressure distribution network and observation pipes.

The ratio of sand filter effluent that is recirculated ranges between 3:1 to 5:1. The result of recirculation is that the wastewater applied to the sand filter is diluted and contains more oxygen than straight septic tank effluent, which eliminates strong odors.

Recirculating sand filters uses a coarser sand (0.8 mm to 3 mm) than single-pass sand filters. Hydraulic loading rates are also higher, generally between three to five gallons per square foot per day. Less land is typically needed using a recirculating sand filter to treat the same amount of wastewater than with other sand filter designs.

The final sand filter effluent has BOD_5 and TSS of generally less than 30 milligrams per liter. Since the sand filter effluent is re-circulated back to the re-circulation tank, where it mixes with anaerobic septic tank effluent, a portion of the nitrogen is lost to the atmosphere through a natural biological process called *denitrification*. The end result is that less nitrogen would enter the soil, important in sensitive areas across Minnesota.

Performance in Minnesota

At NERCC, the replicated single-pass sand filters designed for a flow of 250 gallons per day have operated successfully since October 1996. The sand filters have shown excellent removal of BOD5 (<10 milligrams per liter), TSS (<5 milligrams per liter), and fecal Coliform bacteria (<750 MPN per 100 milliliters). The sand filters at NERCC, although not designed to remove nutrients, have removed some nitrogen (12%) and phosphorus (40%). The sand filters will continued to be monitored in 1999. Lake Washington tests have had similar results.

Operation and Maintenance

Most sand filter operation and maintenance requirements are simple but should be performed by a qualified professional. How much maintenance is needed varies with each design. Routine maintenance typically includes flow monitoring, septic tank pumping, and cleaning effluent screens. The distribution network in the sand filter should be flushed periodically (annually). Electrical components, such as pumps and timers, need to be checked and serviced according to manufacturer recommendations. Pumps, pipes, valves, and other system components also need to be checked on a regular basis.

Figure 5. The Lake Washington recirculating sand filter, designed for a single-family home, shows the support framing, liner material and top of the sand media. The PVC pipes are clean-outs.

How Much Do Sand Filters Cost?

Exact costs for sand filter construction, operation, and maintenance depend on site conditions, filter design and local costs for materials, trucking, and labor. The cost for a septic tank, pump tank and controls, and a system to disperse sand filter effluent into the natural soil also needs to be factored in when evaluating the overall cost of a system. Construction of sand filters usually is economical because they can be constructed or assembled on-site using local labor and materials. Two significant factors that affect cost of sand filter treatment are land and sand media costs. In areas where media is expensive or needs to be hauled a long distance, costs can be much higher.

Figure 6. Maintenance of sand filter systems is required to ensure that they are operating properly. This tube is being used to measure the scum and sludge depth in the septic tank. Some monitoring equipment is shown in the background.

For additional information about sand filters, you can contact the Minnesota Extension Service, the author of this publication at the Natural Resources Research Institute-UMD at 800-234-0054, or the National Small Flows Clearinghouse at 800-624-8301.

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