SLOW SAND FILTERS

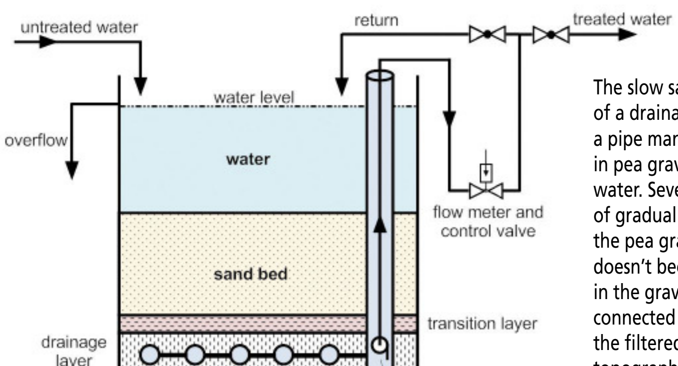
A biological treatment technology to remove plant pathogens from irrigation water proves both efficient and economical, if designed and implemented appropriately.

By Bruno J.L. Pitton, Lorence R. Oki, and Sarah A. White

Recycled irrigation runoff water is a viable alternative for nursery and greenhouse production. However, it is likely to have plant pathogens present, including viruses, water molds, fungi, nematodes and bacteria. To prevent plant pathogen spread, recycled irrigation water needs to be disinfected. Typical sanitation techniques include using chemicals (such as, chlorine products or ozone), heat treatments or ultraviolet light to kill pathogens.

An alternative to these energy and chemical intensive methods is slow sand filtration (SSF), an old technology that has been used in European horticulture since the 1990s and for drinking water since the 1800s. SSFs are capable of removing human pathogenic bacteria and viruses from drinking water and were used to stop a cholera outbreak in the drinking water supply of Altona, Germany, in 1892.

SSFs can easily be confused with rapid sand filtration. Both of these technologies use sand as a substrate, although they are designed to achieve



The slow sand filter (SSF) consists of a drainage layer that includes a pipe manifold assembly buried in pea gravel to collect treated water. Several layers of aggregate of gradually decreasing size cover the pea gravel so that the sand doesn't become incorporated in the gravel. The manifold is connected to a pump that moves the filtered water to storage. If topography enables it, the system may be entirely or partially gravity driven. Flow control is key for effective treatment.

A concrete walled SSF under construction showing PVC pipe drain manifold and larger aggregate to keep sand from clogging drain. The lower orange line is the height of large aggregate, and the higher orange line is the height of filter sand.

The same concrete walled SSF filter finished before initiating water flow. The PVC pipe around the rim of the concrete is the inflow manifold. As this was in the Mid-Atlantic U.S., a building was built to protect the SSF from freezing.

different goals. Rapid sand filters utilize very coarse sand grains (>1 mm) and operate at high flow rates (2 to 20 gpm per square foot of sand bed) to remove particulates from irrigation water. In comparison, SSFs use medium sand grains (<0.6 mm) with very slow flow rates (0.06 to 0.2 gpm per square foot) to remove pathogens.

SSFs eliminate numerous plant pathogens and have been shown to remove water molds, viruses, fungi and bacteria. SSFs can remove pathogens via physical filtration processes, but the sand mainly acts as a substrate for microbial growth. The microbial layer that forms on the sand particles is a diverse community consisting of algae, actinomycetes, fungi, bacteria, protozoa, rotifers, flatworms and nematodes that are the major mechanism of pathogen filtration. This microbe community is called "schmutzdecke," a German term that translates to "dirty skin" or "dirt layer." Most of the biofiltration performed by the schmutzdecke occurs within the top six inches of the sand bed and is predominantly an aerobic process. SSFs do not completely sterilize the water, which leaves a diverse, nonpathogenic microbial community that may provide other benefits.

Specifications:

- Sand quality
  - Size: about 60 to 30 mesh (0.3 to 0.59 mm diameter)
  - Uniform: uniformity coefficient (UC) <3
  - Shape: rounded grains, not sharp sand
- 3 feet of water over sand bed
- Sand must stay submerged
- Sand surface must not be disturbed
- Flow control is required
- Recommended sand bed depth of 3 feet
- Recommend at least two filters: one to remain operational while the other is serviced

SSF components

SSF systems are very simple. The sand filter can be constructed in any container that can hold sand and water: for example, drum, steel water tank, concrete septic tank or earthen, lined reservoir. Sand filters are constructed with an under drain so that treated water can be collected once it has passed through the sand bed (see Figure 1).

Other components that are required include: a reservoir to hold captured runoff, a reservoir to store treated water, and a method (such as a pump) to move the water between these components.

Management

Management of the SSF system requires frequent monitoring of water flow through the filter. If the flow rate is too fast, complete treatment may be compromised and the sand bed may quickly become plugged. The consequence of an exceedingly slow flow rate is that the desired volume of treated water is not generated.

When the desired flow rate cannot be achieved, then the sand bed needs

The submerged sand layer of a 40-inch diameter SSF designed to treat runoff from 27,000 square feet of research greenhouses. The float valves control inflow via the PVC manifold when the water level drops. The flow through the sand bed is controlled on the outflow.

An SSF in the corrugated tank (background) with a plastic tank (foreground) for storing the treated water until use. Due to low flow rates, filtered water needs to be stored to ensure there is ample water supply for irrigation.

maintenance. This requires draining the sand filter to expose the bed surface. The top layer of sand (about .5 to 1 inch) is removed and the sand bed is resubmerged. The water running through the scraped sand bed should be returned to the reservoir capturing untreated water for at least one day before returning the filter into service.

The interval for cleaning the sand surface can vary widely, but could be two months or longer if the filter is operating correctly. The cleaning interval is affected by schmutzdecke growth rate, temperature, pathogen load in water, flow rate and, most importantly, particulates in the water. If there is too much suspended particulate matter (peat, coir, soil) in the recycled water, the SSF will clog very rapidly and require frequent cleaning. To avoid this, installation of a particulate filter, typically the finest mesh available or a settling tank or pond, before the SSF is crucial.

Nursery applications

The advantage of SSF systems is the low requirement of additional inputs versus other treatment technologies. Chemical (such as, chlorine, chlorine dioxide or ozone), radiation (UV) or heat requires chemicals or energy to provide the treatment. Slow sand filters only require energy to move water, which is not different than any other treatment system, without the additional needs of chemicals or energy. Due to the lack of energy and chemical inputs, once installed, SSFs are fairly inexpensive to operate.

The tradeoff for these systems is space. A flow rate of 4 to 6 inches/hour through the sand bed is recommended. One square foot of sand bed surface area operating at a flow rate of 6 inches/hour translates to 3.7 gallons/hour. This is about 90 gallons per day per square foot of sand bed area. For example, we studied an approximately 50-acre nursery that grows container plants on gravel beds. The nursery generates 130,000 gallons of runoff per day; they would require a 42-foot-diameter sand filter or about 1,440 square feet of surface area.

An additional benefit of SSFs is that they do not remove significant amounts of fertilizers from the recycled irrigation water. This water can be reapplied as irrigation without reinjecting the full complement of fertilizers, which can save growers money on a plant nutrition program.

Pathogen removal

SSFs have been shown to remove water molds (*Phytophthora* spp. and *Pythium* spp.), viruses (Tobacco Mosaic Virus; TMV), fungi (*Fusarium* spp.) and bacteria (*Xanthomonas campestris*) from irrigation runoff water. There is potential to remove nematodes (*Radopholus similis*) as well. The time it takes the schmutzdecke to develop for pathogen removal can vary depending on pathogen type and may be temperature-dependent. In research trials, it has taken up to two weeks for *Phytophthora* and *Pythium* removal and up to nine weeks for removal of TMV. Cooler temperatures can affect schmutzdecke development by reducing microbial community growth. However, once the schmutzdecke has developed to remove a particular pathogen, it will filter that pathogen for the longevity of the filter, excluding the 24-hour periods after filter maintenance.

As an added benefit, SSFs may be

Septic tanks are good prefabricated vessels for building SSFs. This installation will have two tanks with sand surface dimensions of 5 feet by 10 feet. At 50 square feet for each, these two tanks will be able to treat a total of 9,000 gallons per day (90 gpd per sq. ft. per tank).

able to remove some pathogens without previous exposure. An SSF exposed to *Fusarium oxysporum* eliminated *Phytophthora capsici* from the filtered water without previous exposure to *P. capsici*. In the same trial, a pump failure was simulated by turning off the water supply to the top of the SSF. After seven days, flow was resumed and *Phytophthora* was removed immediately. It is important to point out that the water above the sand bed was maintained to keep the schmutzdecke from drying out. Desiccation of the schmutzdecke may result in an ineffective SSF for a prolonged amount of time.

SSFs are good, low-cost and low-tech systems for purifying recycled irrigation runoff water at nurseries and greenhouses. They have the ability to remove a variety of plant pathogens via biological filtration and require minimal maintenance. As flow rates are slow, SSFs may need to be fairly large for treating the significant volumes of runoff water generated by container production operations, but if a grower has space, they can be much cheaper than alternative methods. Additionally, two filters are recommended to reduce down time while filter maintenance is performed.

Bruno J. L. Pitton is Staff Research Associate in the Department of Plant Sciences at the University of California, Davis; he can be reached at bjpitton@ucdavis.edu.

Lorence R. Oki is Cooperative Extension Specialist in Landscape Horticulture and Co-Director of the UC Nursery and Floriculture Alliance at the University of California, Davis; he can be reached at lroki@ucdavis.edu.

Sarah A. White is an Associate Professor in the Department of Plant & Environmental Sciences at Clemson University, Clemson, South Carolina; she can be reached at swhite@clemson.edu.

References

Merhaut, D. J. (2008). Water recycling in nurseries. "Greenhouse and nursery management practices to protect water quality." J. P. Newman. Oakland, CA, University of California Agriculture and Natural Resources Communication Services: 98-100.

Newman, J. P., J. N. Kabashima, D. Merhaut, D. L. Haver, J. Gan and L. R. Oki (2014). Controlling runoff and recycling water, nutrients, and waste. "Container nursery production and business manual." J. P. Newman. Richmond, CA, University of California Agriculture and Natural Resources Communication Services: 108-110.

Oki, L. R., L. L. Nackley and B. Pitton (2016). "Slow sand filters: a biological treatment method to remove plant pathogens from nursery runoff©", International Society for Horticultural Science (ISHS), Leuven, Belgium.

Oki, L. R., L. L. Nackley, B. J. L. Pitton, S. Bodaghi, E. Lee, D. L. Haver and D. M. Mathews (2016). "Slow sand filters remove Tobacco Mosaic Virus." "UCNFA News" 20(2).