Using Slow Sand Filters to Remove Plant Pathogens From Irrigation Runoff©

Michael A. Harris and Lorence R. Oki
Department of Plant Sciences, University of California, Davis, California 95616
Email: lroki@ucdavis.edu and maharris@ucdavis.edu

INTRODUCTION

What Is Slow Sand Filtration? Slow sand filtration (SSF) is an old water treatment technology that is reappearing in horticultural applications in Europe, but isn't yet in widespread use in the U.S.A. A common misconception is that SSF and rapid sand filtration are the same but with different flow rates. Though they use the same type of substrate they are quite different in that SSF is a biological treatment method that can remove pathogens (Wohanka, 1995), whereas rapid sand filtration is a physical filtration process.

Rapid sand filtration systems have the following characteristics:

- Utilize coarse sand grains larger than 1 mm in diameter
- Remove larger particles only
- Do not remove pathogens
- Do not remove pollutants
- Have a high treatment capacity of 18–180 gpm/yd^2 of bed surface area
- Are relatively low maintenance, which can be automated

In comparison, slow sand filtration systems:

- Can remove pathogens
- Can remove pollutants
- Are also low maintenance
- But have low treatment capacity of 2–4 gpm/yd^2 of sand bed area

Some physical filtration in SSFs occurs when particulates in the water become lodged in the sand surface, thereby decreasing the effective pore size. In order to delay this fouling, pretreatment may be desirable for turbid waters. As water moves through the sand bed, a biofilm develops on the surface of the sand grains and can become relatively thick at the surface of the sand bed. This thickened layer, also known as the "schmutzdecke," is primarily responsible for the treatment. The biofilm is a diverse and dynamic community of microorganisms and its composition depends on the contents of the water and changes in response to variations in that content. Most of the biological activity occurs at the surface and in the 15 cm just below the sand surface. Organisms that have been identified in the biofilm include algae, bacteria, diatoms, and zooplankton (Calvo-Bado et al., 2003; Joubert and Pillay, 2008). However, the specific mechanisms of treatment are not fully understood.

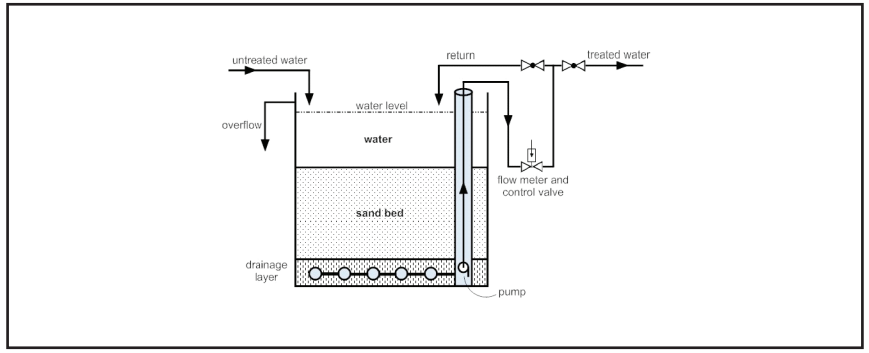

Figure 1. Slow sand filtration system showing sand bed, under drain layer, and pump. Flows are monitored and controlled to optimize treatment. When untreated water levels are low, treated water is returned to the filter to keep the sand bed submerged.

Specifications of SSF systems include:

- Sand quality
  - Size: about 60 mesh (0.3 mm diameter)
  - Uniformity: uniformity coefficient (UC) <3
  - Shape: rounded grains, not sharp sand
- 1 m of water over sand bed
- Sand must stay submerged
- Sand surface must not be disturbed
- Flow control is required
- Recommended sand bed depth of 1 m
- Recommend at least 2 filters: 1 to remain operational while the other is serviced.

Slow Sand Filtration Components. Slow sand filtration systems are very simple. The sand filter can be constructed in any container that can hold sand: e.g., 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. (Fig. 1).

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

Management. Management of the SSF systems requires frequent monitoring of the flow of water 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 a slow flow rate is the generation of the desired volume of treated water and a potential to degrade the biofilms due to lack of sufficient aeration and carbon supply.

When the desired flow rate cannot be achieved, then the sand bed needs maintenance. This requires draining the sand filter to expose the bed surface. The top layer of sand (about $^1/_2$–1 in.) is removed and the sand bed re-submerged. The water running through the scraped sand bed should be returned to the reservoir capturing untreated water for at least 1 day before returning the filter into service.

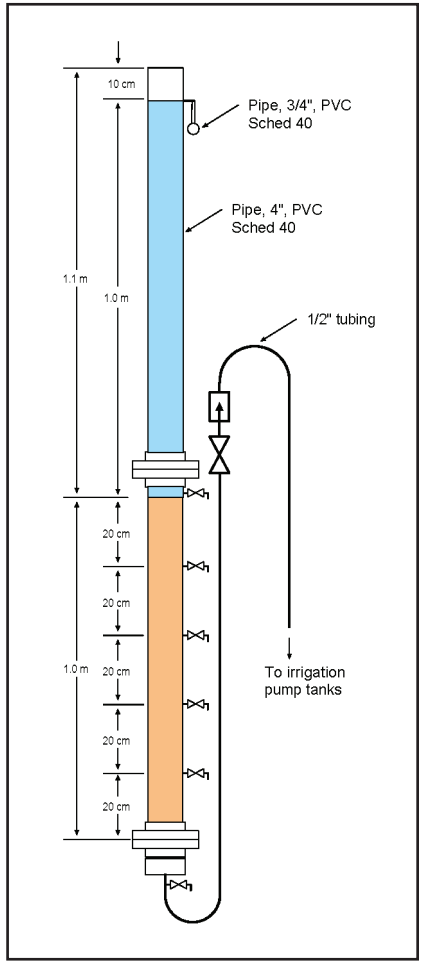

Figure 2. Sand filters for experimentation were constructed of 4-ft PVC pipe and included valves that enabled collecting samples above the sand bed, at 20-cm intervals down the sand bed, and below the bed.

Nursery Applications. Slow sand filters are effective in removing pathogens and other pollutants, including nutrients. The advantage of these systems is the low requirement of additional inputs. Chemical (e.g., chlorine, chlorine dioxide, or ozone) or radiation (e.g., UV) treatment 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, but there are no additional needs of chemicals or energy.

The tradeoff for these systems is space, however. A flow rate of 4-6 in./h through the sand bed is recommended. One sq. yd. of sand bed surface area operating at a flow rate of 6 in./h translates to about 90 gal/day/sq. ft of sand bed area. For example, 4 ft × 8 ft square septic tank (totaling 48 sq. ft) could treat about 4,300 gal/day. To treat 100,000 gal/day, two tanks of 27-ft diameter would be needed.

If treated runoff is integrated back into the irrigation system, residual nutrients can supplement a plant nutrition program. However, if the treated water is stored, the nutrients can promote algal growth and become problematic.

Experimentation. Experiments at UC Davis examined how flow rates affected the treatment of runoff generated from a simulated nursery condition. The runoff was captured daily, transferred into a holding tank, and inoculated with *Phytophthora capsici* zoospores. The water was then introduced into sand filters made using 4-in. PVC pipe that included sampling ports (valves) located just above the sand bed surface, at 20-cm intervals down the sand bed, and below the sand bed (Fig. 2).

The sand bed was constructed using cleaned sand conforming to the size and uniformity specifications stated earlier. Water samples of 500 mL were collected from each port every 5 days for 30 days beginning the day after the treatment water was introduced into the filters. Two aliquots of the water samples were passed through

0.22-μ filters and the filters placed onto PARP-H culture media in petri plates. After 24 h, the filters were removed and after an additional 24 and 48 h colony-forming units (CFU) were counted. Three flow rates were tested: 150, 250, and 500 $L \cdot m^{-2} \cdot h^{-1}$. Flows were checked and flow controls were adjusted daily to maintain the desired flows. The test was repeated three times.

The treatment rate of 150 $L \cdot m^{-2} \cdot h^{-1}$ had the most favorable results in terms of propagule removal and flow consistency. At 500 $L \cdot m^{-2} \cdot h^{-1}$ the filter fouled after 5–10 days of operation. The fouling caused flow rates to decrease, eventually reaching no flow. Two to five days after reaching zero, however, flows rebounded. This rapid decrease in flow rate was not seen in either the medium or the slow rates (250 and 150 $L \cdot m^{-2} \cdot h^{-1}$, respectively).

A second experiment was conducted by setting up five sand filters as described above at U.C. Davis. Simultaneously, five additional filters were set up in Felton, California, and water from Lompico Creek was provided to the filters. This creek in known to be a source of *P. ramorum*, the organism that causes sudden oak death disease.

After 30 days, the filters at U.C. Davis were moved to Felton and provided the source of stream water. Water samples of 700 mL from just above and just below the sand bed were collected. A fresh d'Anjou pear was immersed into each sample for 24 h then removed to dry plastic containers. Approximately 48 h after removal, the pears were examined and a small plug of tissue from infection sites were placed onto PARP-H medium. Samples were incubated for another 48 h and the colonies were counted. Colonies that formed were used to identify pathogen species where it was possible to do so. This experiment was conducted twice.

It was found that the sand filters established in Davis using *P. capsici* were able to remove *Phytophthora* spp. from the creek water. *Phytophthora ramorum* was detected in the stream water on the second experiment trial, along with *P. gonopodioides*, other *Phytophthora* spp., and *Pythium* spp.

FUTURE WORK

Mobile Environmental Solutions Inc. (Irvine, California) has developed a horizontal flow vegetated biological treatment system using an engineered gravel substrate and bulrush (*Schoenoplectus* sp.). These systems have been shown to remove 99-99.9% of coliforms and viruses and will be tested in combination with SSFs. The pairing of these systems may result in a highly efficient, low input method to treat captured irrigation runoff.

LITERATURE CITED

Calvo-Bado, L.A., T.R. Pettitt, N. Parsons, G.M. Petch, and **J.A.W. Morgan.** 2003. Spatial and temporal analysis of the microbial community in slow sand filters used for treating horticultural irrigation water. Applied and Environmental Microbiology. 69:2116–2125.

Joubert, E.D., and **B. Pillay.** 2008. Visualisation of the microbial colonisation of a slow sand filter using an environmental scanning electron microscope. Electronic Journal of Biotechnology. 11(2): [cited 09 Nov 2009]. Available from: <http://www.ejbiotechnology.info/content/vol11/issue2/index.html.> ISSN: 0717-3458.

Wohanka, W. 1995. Disinfestation of recirculating nutrient solutions by slow sand filtration. Acta Hort. 382:246–255.