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Using SDI to effectively irrigate with biological effluent

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Abstract. *Subsurface drip irrigation is a viable method for irrigating with biological effluent. Proper care must be exercised in the design and management of the SDI system to prevent emitter clogging and the resulting poor system performance or complete loss of the irrigation system. The proper precautions can be categorized into: 1. Select the proper components (emitters), 2. Filter the effluent adequately, 3. Suppress biological growth and chemical precipitation, 4. Flush the driplines occasionally, and 5. Monitor the system so small problems don't become large problems. This paper summarizes some of the recent research addressing those five steps. Recent research is developing emitters that are less susceptible to clogging by refining the flow path length, cross-section flow area, internal emitter geometry, and other factors. Biofilm research is identifying the mechanisms of biofilm formation and clogging, thus creating a path to potential solutions to clogging because of biological hazards. Filter testing studies are identifying which filter technology is providing adequate protection of the emitters and outlining filter and backwashing management recommendations. Biological control has historically been accomplished with chlorination; that technology is mature and effective. Biological control with antagonistic bacteria also holds promise for prevention of emitter clogging due to biological activities. Flushing has been a standard practice but has received little research focus until recently. Finally, advances in controls, sensors, and data communications will make remote monitoring and automation more practical and widespread.*

Keywords. Subsurface drip irrigation, SDI, biological effluent, wastewater, emitter clogging

Introduction

Biological effluent, sometimes called wastewater, can be an important resource in many areas. Some sources of biological effluent include animal production facilities, municipalities, and households. The efficient use of biological effluent for irrigation brings many advantages (Trooien and Hills, 2007; Gushiken, 1995). Using subsurface drip irrigation (SDI) brings even more advantages. Those advantages are exploited in many ways and in areas, including various locations in the United States and many locations worldwide, from Argentina to Tunisia (Asano et al., 2006). One advantage of using SDI is the nitrogen losses are reduced compared to simulated low energy precision application (LEPA) of the effluent (Lamm et al., 2007). This results in reduced leaching and volatilization and a greater percentage of the nitrogen in the effluent available to the crop, even though increased uptake was not measured.

Prevention of emitter clogging is the key to long irrigation system life. Emitters can be clogged due to biological, physical, or chemical processes. Recent evidence points to biofilms as a major cause of biological emitter clogging (Cararo et al., 2006). Yan et al. (2009) used scanning electron microscopy to show that biological clogging was caused by particles and extracellular polysaccharides that combined to clog emitter pathways. Additionally, physical clogging can be caused by sediment getting caught in the corners of the tortuous flow pathway (Cararo et al., 2006). Effluents often have high solids concentrations. Finally, chemical precipitation can also cause clogging when irrigating with effluents (Liu and Huang, 2009).

To effectively irrigate with effluent using microirrigation in general, and SDI in particular, requires appropriate protection of the system to prevent emitter clogging. Five steps have been identified to adequately protect the emitters from clogging (Trooien and Hills, 2007). They are:

1. Select the proper components (emitters),
2. Filter the effluent adequately,
3. Suppress biological growth and chemical precipitation,
4. Flush the driplines occasionally, and
5. Monitor the system so small problems don’t become large problems.

This paper will summarize some of the recent research addressing the five steps. The focus will be on research since the development of Trooien and Hills (2007).

Component (emitter) selection

Many different emitters and emitter types have been evaluated for their suitability for use with effluents. Some of the emitter characteristics most often cited as important for clogging prevention are flow path length, cross section flow area, and internal emitter geometry. Emitters with shorter flowpaths have been suggested as less susceptible to clogging (Cararo et al., 2006; Yan et al., 2009). Within three different emitter types, degree of clogging was shown to be positively correlated to pathway length (Cararo et al., 2006). Dentate spacing (Fig. 1) was shown to be especially important in preventing physical clogging as a result of testing 16 different combinations of geometries and sizes (Li et al., 2006). Smaller cross-section flow area has been shown to be a greater risk for biological clogging (Li et al., 2009) and chemical clogging (Liu and Huang, 2009). Dentate angle and height were also important factors but combinations were more important than maximizing any one specific factor. In addition, asymmetrical dentate structures within the emitter may be less susceptible to clogging (Yan et al., 2009). The best performing emitters for applying effluent consisted of a flat body style with a rectangular elastic membrane (pressure compensated and self-cleaning device) and relatively short pathway (Cararo et al., 2006). It is interesting to note that a pressure-compensated emitter that performed well under the testing of Cararo et al. (2006) also showed flow rate reduction of only 7% after 4 years of operation in a field study (Lamm et al., 2002) and performed well in another field test (Duran-Ros et al., 2009a).

Emitter manufacturing method has also been noted as a factor in clogging susceptibility. Two of the four tested molded and welded emitters were more susceptible to clogging than were pressure-compensated on-line emitters (Duran-Ros 2009a). The susceptible molded emitters included a pressure-compensated model and one that was non-compensated and had the smallest cross-sectional flow areas in the test. All emitters had relatively high flow rates (>2 L/hr). Previous studies had noted that molded emitters were less susceptible to clogging than were indented emitters. Greater manufacturing variability (measured by CV) also increases the susceptibility to clogging (Li et al., 2009; Liu and Huang, 2009).

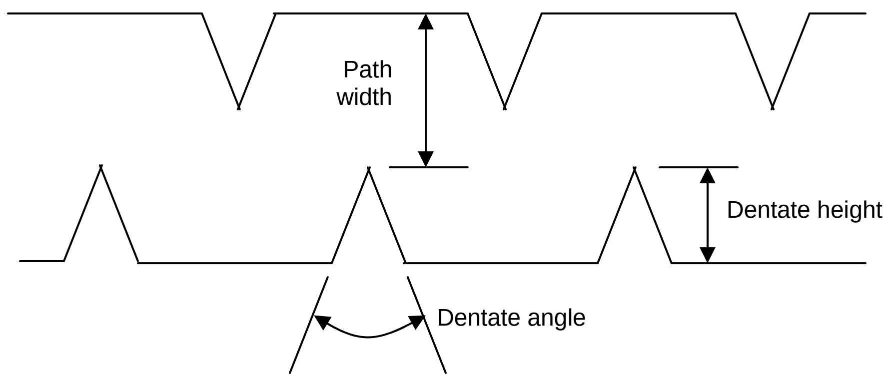

Figure 1. Internal geometry of drip emitter dentate structure (Yan et al., 2007).

Pressure-compensating emitters can have advantages that overcome hydraulic shortcomings that might cause nonuniform flow rates from non-PC emitters caused by pressure changes within the dripline. When water is flowing through a pipe, some pressure change is unavoidable because of the pressure loss due to friction. But even pressure compensating emitters can act as non-pressure-compensating emitters at low pressures (Duan et al, 2008).

Emitters at the distal ends of driplines appear to be more susceptible to clogging when using clean water (Duran-Ros et al., 2009a; Li et al., 2009; Puig-Bargues et al., 2009). However, emitter clogging when using effluent can be more random (Li et al., 2009).

Filtration

Filtration of effluent is especially important because effluents often have higher solids concentrations and biological loads than other water sources. To reduce the hazard of physical clogging, the recommendation of filter opening size of 0.1 times the emitter opening size is still appropriate (Li et al., 2009).

Sand media and disk filters have been used in various implementations of effluent irrigation with SDI. Direct comparisons have shown that a combination of sand and screen filtration protected emitters better than disk or screen filtration (Duran-Ros et al., 2009a). That is, emitters protected by screen and sand filtration had the least reduction of flow rate and the end of the test. Only the sand filtration step actually reduced the solids concentration and turbidity. In fact, screen, disk, and combination of screen and disk filtration- in some cases- didn't reduce solids concentration or turbidity (Duran-Ros et al., 2009a, 2009b). Other reports have demonstrated that relatively lower-cost disk filtration was adequate to protect emitters even through media filtration performed better (Capra and Scicolone, 2005).

To keep any filter operating properly, periodic backwashing is required to keep the filter clean. The time between backwashing operations will vary inversely with the solids concentration of the effluent. This effect is shown in the measurement of pressure differential across disk filters of four opening sizes during the filtration of biological effluent from 10 different animal facilities (Fig 2). As the solids concentration increases, the filter will clog more quickly. Similarly, as the size of the openings in the filter decreases, the filter will clog more quickly and require more frequent backwashing. Filters with very small openings, such as 200 mesh, require very frequent backwashing when filtering the solids contents often found in biological effluents.

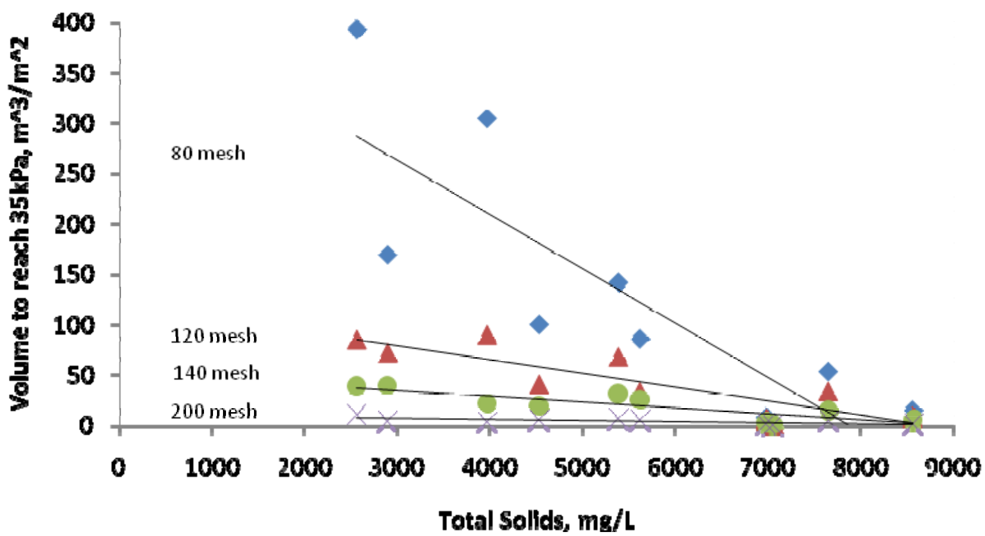

Figure 2. Volume of biological effluent from beef or swine lagoons passing through a disk filter before the pressure differential reaches 35 kPa (5 psi). The mesh sizes are 80 mesh (openings of 200 um), 140 mesh (openings of 130 um), 120 mesh (openings of 115 um), and 200 mesh (openings of 55 um). Each point shown is the average of four replicates. The volume shown is the volume of effluent per area of the filter (unpublished data, Trooien and Lamm, 1999).

Where disk filtration is used, higher backwash pressures (500 kPa, or 72 psi) have been shown to be more efficient, resulting in greater reduction of differential pressure after the backwash (Duran-Ros et al., 2009b). Booster pumps or other hydraulic adjustments may be required to achieve such high pressures in SDI systems.

Suppression of biological growth and chemical precipitation

The most common method of biological control in driplines is chlorination. Chlorination at a concentration of 0.5 g/m^3 has been shown to be effective at preventing ("attenuating") emitter clogging (Cararo et al., 2006). When chlorinating effluents with high ammonia concentrations, additional injections, such as acid, to control pH may be required to get adequate biological control with the chlorine. Many animal effluents have ammonia concentrations great enough to cause this concern.

Attempted cleaning with compressed air at a relatively low pressure of 1.96 kPa (0.3 psi) was not effective for clogging prevention (Cararo et al., 2006). Higher pressures such as 490 to 980 kPa (70 to 140 psi) may be more effective (Keller and Bliesner, 1990) but extra care and safety measures will be required at such high pressures. Some materials, such as thin-walled driplines (tapes) may not be able to withstand these pressures so this method may not be appropriate for them.

If the cause of emitter clogging is biological, another potential cleaning method is the use of antagonistic bacteria (Sahin et al., 2005). Two strains of Bacillus and one strain of Burkholdria were tested against 25 fungi isolates and 121 bacterial strains from greenhouse driplines known to have clogged emitters. The isolated fungi and bacteria were used to clog a 12-m dripline under laboratory condition. Solutions containing the antagonistic bacteria were introduced to the tested dripline two different times, 48 hours apart. After 14 days of daily operation, the flow rate of the tested dripline had recovered from about 5% (nearly completely clogged) to 100% of design flow rate. The flow rate of the control (untreated) dripline did not change during the same time period.

Dripline flushing

Adequate velocity within the dripline is required for a flushing operation to transport sediment to the end of the dripline. The flushing velocity often recommended is 0.3 m/s (ASAE, 2003). That recommendation holds for SDI systems that apply effluent, although greater velocities appear to be able to remove more sediment from the driplines.

When flushing sediment from thin-wall dripline, increased flushing velocity tends to cause increased sediment transport from the dripline (Puig-Bargues et al., 2009). The only statistically significant difference was a single flush at velocity of 0.61 m/s transporting more sediment than did a velocity of 0.23 m/s. Tested flushing velocities were 0.23, 0.3, 0.46, and 0.6 m/s. Although clogging was minimal (the greatest reduction of emitter discharge was only 2.5% of the initial discharge), any clogged emitters were located at the distal ends of driplines. Clogging in this study was physical, caused by sediment in the water. At the end of the study, sediment located within the unflushed dripline was concentrated near the inlet of the dripline even though any clogged emitters were at the distal end of the dripline. Sediment in driplines with lower flushing velocities also tended to accumulate near the inlet but sediment in driplines with higher flushing velocities tended to accumulate at the distal ends of the driplines. They suggested that increasing the flushing duration may be a less complicated and more cost-effective means of improving sediment removal.

Monitoring

Emitter clogging is usually a gradual process. Thus, proper monitoring can detect a clogging issue when it is still minor and recoverable.

The monitoring requirements for continued SDI system operation and maintenance lend themselves well to automation. Automated backwash systems and valve or pump controls have been in operation (e.g. Trooien et al., 2000). But many additional monitoring tasks can be automated. Some of those additional tasks include pressure and flow monitoring in laterals and filters (Duran-Ros et al., 2008). Additionally, systems can be connected to the internet for remote control and access to data (Duran-Ros et al., 2008). This area of application holds much promise for reducing labor requirements of SDI/effluent systems.

Conclusion

Successful irrigation with biological effluent and SDI is possible if the system is properly designed, installed, and managed. Prevention of emitter clogging is essential to keep the system operating properly. Clogging may be caused by biological, physical, or chemical factors. Biofilm research is teaching us more about the structure and formation of biofilms, which will allow us to design and manage systems to avoid such clogging in the future. Implementing the five steps- component selection, filtration, growth and precipitation suppression, dripline flushing, and monitoring- can make successful irrigation possible. Recent research efforts are making progress in all of these areas. Emitter testing and design studies are identifying sizes and geometries that are less susceptible to clogging. Filter research is illuminating the effectiveness of various technologies and outlining management strategies to keep filters operating properly. Chemical injection and biological control research is showing us what works and developing novel control methods. Dripline flushing research is telling us how effective our flushing strategies are and raising possibilities for more efficient and cost-effective flushing methods. Monitoring, control, and communication technologies are enabling advances that can reduce the labor requirements for keeping SDI systems operating properly. These steps and other advances will continue to help us design, install, and manage successful SDI systems to make efficient use of our effluent resources.

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