Drip irrigation with biological effluent

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This paper presents a brief overview of the application of biological effluent with microirrigation systems. In this paper, "biological effluent" is considered to be water that contains impurities derived from biological sources. Such impurities include human and animal metabolic wastes and domestic and industrial food processing wastes.

There are many potential advantages to applying biological effluent with microirrigation systems, especially drip irrigation systems. Advantages include (Gushiken, 1995; Trooien et al., 2000):

- Overspray and drift are minimized so liability exposure is minimized,
- Potable water resources are conserved,
- Pressure requirements are often reduced,
- Unusual field shapes and sizes are easier to irrigate in their entirety,
- Nutrients in the effluent can be utilized by the crop,
- Irrigation system corrosion is reduced because most of the system is made of plastic, and
- Cost/benefit compares favorably to other methods in some situations.

Additional potential benefits can be realized when using subsurface drip irrigation (SDI) systems (Gushiken, 1995; Trooien et al., 2000):

- Human contact and associated health risks are reduced,
- Spacing requirements from populations or other facilities are reduced because overspray and drift are eliminated,
- Vandalism is reduced,
- Application uniformity is high resulting in better control of the applied water, salts, and nutrients,
- Effluent is applied directly into the root zone reducing the potential for runoff,
- The soil surface stays dry, reducing weed germination and bacteria survival near the soil surface, and
- Weather constraints such as high wind or low temperatures are reduced or eliminated.

In this paper, we will consider biological effluent to be a resource so the approach will be efficient use of the resource rather than disposal of a waste product.

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Microirrigation system design and management for application of biological effluent

Because of their relatively high concentrations of salts, nutrients, and biologicals, effluents pose an increased risk of emitter clogging. Emitter clogging can be avoided by meeting these five criteria:

1. selecting and installing the proper system components,
2. filtering the effluent properly and effectively,
3. suppressing biological growth and chemical precipitation effectively,
4. flushing materials that may accumulate in the distribution systems, and
5. monitoring system performance to assure that partial clogging is treated before it becomes catastrophic.

System components

Emitters with smaller flow rates (within a single emitter type) are more susceptible to clogging (Ravina et al., 1992). Using emitters with low flow rates is an advantage because zone sizes can be larger and control hardware requirements are reduced. Using thin-walled collapsible hose (drip tape) can also be appropriate for applying activated sludge secondary treated effluent (Hills and Brenes, 2001), particularly emitters manufactured by attachment or molding. In a test with beef feedlot runoff effluent, the two smallest emitters tested (flow rates of 0.57 and 0.91 L/hr/emitter) showed reduced flow rates after two years of operation (Trooien et al., 2000). Those two smallest emitters were manufactured by indentation. Two larger emitters (flow rates of 1.5 and 2.3 L/hr/emitter), manufactured by attachment, did not decrease in flow rate during the first two years of operation. Adin and Sacks (1991) noted several design factors that could be implemented to reduce clogging potential: shorten and widen the flow path, round the straight edges on protruding teeth in the flow path, remove dead areas in the flow path, design the orifice entrance to act as a barrier to keep large particles out of the emitter, and place seams away from the flow path or remove seams entirely.

Filtration

Filtration is required to prevent large particles from entering driplines and physically clogging emitters. Physical clogging begins at the distal ends of driplines (Ravina et al., 1992). Particles accumulate at the distal ends of driplines where flow velocities are reduced (Shannon et al., 1982) unless biological agents intercept them.

Sand media filtration is often considered to be the standard for filtration protection of microirrigation systems. Testing has shown that media filtration (uniform bed with mean particle size of 1 mm) provided the best protection, followed by disk filtration of 140 mesh (Ravina et al., 1997). Screen filtration (155 to 200 mesh) was not as effective in protecting downstream elements. Oron et al. (1980) also found disk filtration (80 mesh) to be slightly better than screen filtration at removing total chemical oxygen demand.

Chemical injection to suppress biological growth and chemical precipitation

Emitters can be clogged by a mixture of biological and inorganic particles, protozoa, or bacteria that grow within the driplines (Ravina et al., 1992; Sagi et al., 1995). Bacterial slimes initiate clogging then suspended inorganic particles adhere to the slimes and cause physical clogging (Adin and Sacks, 1991). Additionally, bacterial growth within driplines may lead to the formation of biofilms. These biofilms include the interactions of microorganisms and the polysaccharide layer they produce (Picologlou et al., 1980). Biofilms can increase pressure loss due to friction along the length of driplines due to (1) reduction of the cross-sectional flow area, (2) oscillation of filaments attached to the biofilms, and (3) increased roughness.

Chlorination is one method used to control biological growth within driplines. Chlorination is especially challenging in effluents with high ammonia contents because chlorine reacts with ammonia to form chloramines. These chloramines are up to 80 times less effective than chlorine for biological control (Feigin et al., 1991).

Chemical precipitation can also be a concern, especially for surface-installed driplines. Acid injection to reduce pH from 7.6 to 6.8 was effective in preventing chemical precipitation-induced clogging in saline fresh water (Hills et al., 1989).

Flushing

Flushing requirements can be reduced with adequate filtration (Tajrishy et al., 1994) but no filtration system can keep all particles out of driplines. A flushing frequency of two weeks was effective for thin-walled collapsible hose when using effluent and the flushing velocity should be at least 0.5 m/s (Hills and Brenes, 2001). In extreme cases, flushing can take place daily (Norum et al., 2001).

Monitoring

Frequent monitoring of system performance can detect clogging before it becomes catastrophic because emitter clogging is progressive and continuous rather than a discrete event (Ravina et al., 1992 and Trooien et al., 2000) and partial clogging of emitters is more common than complete clogging (Ravina et al., 1992). Early detection of emitter clogging is important because chlorination of partially-clogged emitters is more effective than if the emitters are more severely clogged (Ravina et al., 1992).

Irrigating with biological effluent

Successful irrigation with biological effluent requires that the system be designed well, as noted in the previous section. Success also hinges on selecting the proper site and managing the unique characteristics of the effluent- salts, nutrients, and biological pathogens- the extra "stuff" that comes with the water and can be either and advantage or a disadvantage. In the case of nutrients, and added benefit of having nutrients in the water may be a disadvantage if the nutrients are lost to the crop and adversely affect the environment. Other elements, particularly heavy metals, may be of concern but will not be considered here.

Site and Crop considerations

The irrigation site must be located close enough to the effluent so that the effluent can be used economically. In addition, characteristics such as soils, climate, and available crops must be suitable. For example, soils must be permeable enough to allow rapid infiltration or water movement (including vertical drainage) yet hold water long enough to allow interaction of waste constituents such as nutrients with soil minerals, plants, and organisms; have sufficient exchange capacity to temporarily hold effluent constituents; and have sufficient thickness to provide adequate opportunity for water purification. The climate, particularly precipitation and temperature, must be conducive to irrigation. Crops suitable for effluent irrigation with sprinkler systems would also be suitable for microirrigation. Additional crops may suitable for microirrigation because its use reduces viral and bacterial contamination of the crop (Oron et al., 1991, 1992).

Salinity

Some biological effluents can be quite saline. Management of saline effluent requires the same caution and careful management as irrigation with saline fresh water. That is, adequate leaching is required to maintain a favorable salt balance in the root zone. In general, the major salinity issue is the sum of all salts rather than any specific ion, but individual ions such as chloride, sodium, or boron may raise plant toxicity issues. Finally, sodium levels in biological effluent may be elevated. Soil sodium concentration elevation has been measured when irrigating with septic tank effluent with high sodium concentration (Jnad et al., 2001). Elevated soil sodium concentrations, measured by sodium adsorption ratio (SAR) or exchangeable sodium percentage (ESP) can cause soil degradation by causing soil dispersion or swelling, reducing the soil infiltration rate.

Nutrients

Two nutrients are of particular concern when irrigation with biological effluent: nitrogen (N) and phosphorus (P). The total mass application of N, P, and water must be considered so that any one is not applied in excess. That is, effluent should be applied only until the crop requirement plus soil storage capacity for one of the three elements- water, N, or P- is met. Excessive application of N may result in excessive nitrogen leaching. Excessive application of P may result in leaching of mobile forms of organic P or runoff of P attached to soil particles. Excessive application of water will result in excessive runoff, leaching, or both.

In primary treated effluent, N is usually in the forms of ammonium and organic N. In secondary treated effluent, N is often in the form of nitrate. The N loss mechanism of primary concern is leaching with resultant contamination of groundwater resources. Leaching reduction is accomplished by careful management of N and careful water management to prevent excessive water application and resultant leaching. Nitrate leaching is especially rapid in porous, permeable soils where water movement is also the most rapid.

The P loss mechanism of primary concern is runoff carrying soil particles with P sorbed to them. Inorganic P is strongly sorbed to soil particles, making P less prone to leaching. However, some P can be leached (Sims et al., 1998), particularly organic forms of P that are more mobile. Solubility of P is mostly controlled by its concentration in the soil solution. Thus, a balance must be found between making adequate P available to the crop but avoiding excessive concentrations that may be lost.

Pathogens

Since the discovery about a century ago that eating raw vegetables grown on soil fertilized with raw sewage resulted in typhoid fever outbreaks (Gerba et al., 1975), pathogen transfer from effluents to humans has been recognized as a health issue.

Microirrigation appears to be especially well suited to applying effluents with minimal health risk. SDI that leaves the soil surface dry reduces the potential for transfer of bacteria because bacterial survival is reduced in dry soils (Gerba et al., 1975). However, high soil water content deeper in the soil profile is conducive to bacterial survival. Indeed, bacteria (Oron et al., 1991) and viruses (Oron, 1996) have been shown to accumulate in the soil near the driplines. In defense of surface drip irrigation, sunlight has been shown to reduce bacterial survival (Gerba et al., 1975) so surface emitters may reduce bacterial concentrations by exposing applied effluent to sunlight.

When considering or planning irrigation with biological effluent, additional laws and regulations may require additional compliance measures by the irrigator. In the USA, effluent irrigation is often regulated by states or municipalities. Practices that may be required to meet regulations include- but are not limited to- changing crops, performing additional effluent disinfection, or adding effluent stabilization ponds.

In summary, microirrigation application of biological effluent has many advantages. As is true of any microirrigation system, care must be exercised to maintain and protect the irrigation system so that it performs efficiently and as it was designed. Management strategies must be implemented to take advantage of the benefits such as supplying nutrients to the crop while avoiding potential problems.

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