PREVENTION OF EMITTER PLUGGING IN MICROIRRIGATION SYSTEMS

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INTRODUCTION

In the past decade, the use of microirrigation to provide water to horticultural crops has increased dramatically. Microirrigation, properly managed, offers several potential advantages over other methods of irrigation:

1) greater water and nutrient application efficiency,
2) reduced crop water (ET) requirements,
3) minimization of deep percolation and runoff,
4) enhanced weed control,
5) reduced bacteria, fungi, disease, and other pests that require a moist environment, and
6) efficient delivery of chemicals (chemigation) through the irrigation system.

However, the plugging of emitters, the device through which water is discharged, is one of the most serious problems associated with microirrigation use. Emitter plugging can result from physical (grit), biological (bacteria and algae), or chemical (scale) causes. Frequently, plugging is caused by a combination of more than one of these factors.

A properly designed microirrigation system includes preventive measures to avoid emitter plugging. Differences in operating conditions and water quality do not allow a standardized recommendation for all conditions. In general, however, the system should include the following:

1) a method of filtering the irrigation water,
2) a means of injecting chemicals into the water supply,
3) in some cases a settling basin to allow aeration and the removal of solids, and
4) equipment for flushing the system.

PREVENTION OF EMITTER PLUGGING

Prevention of plugging can take two basic approaches: 1) removing the potential source of plugging from the water before it enters the irrigation system; or 2) treating of the water to prevent or control chemical and biological processes from occurring. Both approaches will be discussed. In many cases, a combination of each approach will be applicable.

Water Quality Analysis

Knowing the quality of proposed irrigation water is necessary before designing a microirrigation system. Water quality analyses are performed at water testing laboratories (e.g. IFAS Soil and Water Testing Laboratory, University of Florida, Gainesville). For more information on local testing laboratories, contact your county agent. A water analysis specifically for microirrigation should be requested. Table 1 provides concentration levels for evaluating the water quality analysis in terms of the potential for emitter plugging. If the source is surface water, hydrogen sulfide should not be present and can be omitted.

Table 1. Criteria for plugging potential of micro irrigation water sources.

Factor	Slight	Moderate	Severe
	Plugging Hazard Based on Concentration		
	Concentrations (ppm)		
Physical			
Suspended solids (filterable)	< 50	50-100	> 100
Chemical			
pH	< 7.0	7.0-8.0	> 8.0
Dissolved solids	<500	500-2000	>2000
Manganese	< 0.1	0.1-1.5	> 1.5
Iron	< 0.1	0.1-1.5	1.5
Hydrogen sulfide	< 0.5	0.5-2.0	2.0
Hardness[a]	<150	150-300	> 300
Biological			
Bacteria (population)	<10,000	10,000-50,000	50,000

(Modified from Nakayama and Bucks, 1986)
([a]Hardness as ppm $CaCO_3$, Todd, 1980)

A water quality analysis usually lists electrical conductivity in micromhos per centimeter (mmho/cm). To estimate parts per million (ppm) dissolved solids as shown in Table 1, multiply mmho/cm by 0.64. For example, if the electric conductivity meter reads 1000 mmho/cm then dissolved solids can be estimated as 640 ppm.

Hardness is primarily a measure of the presence of calcium (Ca) and magnesium (Mg) and is another indicator of a water's plugging potential. If Ca and Mg are given in ppm rather than hardness, hardness can be estimated from the following relationship:

$$\text{Hardness} = (2.5 \times \text{Ca}) + (4.1 \times \text{Mg}), \qquad \text{(Eq.}$$

where Ca and Mg are given in milligrams per liter (mg/L or ppm). Note that 1 mg/L equals 1 ppm. If the analysis lists the Ca and Mg concentrations in milliequivalents per liter (meq/l), they can be converted to ppm by the following factors:

$$\text{Ca (meq/L)} \times 20 = \text{Ca (ppm)}, \qquad \text{(Eq. 2)}$$
$$\text{Mg (meq/L)} \times 12 = \text{Mg (ppm)}. \qquad \text{(Eq. 3)}$$

Results from this method of estimating hardness may vary somewhat from results obtained for total hardness by other methods; however, the estimate is normally adequate for use in Table 1.

Filters for Prevention of Physical Plugging

Many types of microirrigation filter systems perform adequately and are commercially available. Important factors to consider in selecting a filtering method are emitter design and quality of the water source. Consider the emitter's minimum passageway diameter when selecting the filter mesh size. Filters should be sized according to the emitter manufacturer's recommendations or, in the absence of manufacturer's recommendations, to remove any particles larger than one-tenth the diameter of the smallest opening in the emitter flow path.

Screen filters come in a variety of shapes and sizes. A typical design is shown in Figure 1. Screen material may be slotted PVC, perforated stainless steel, or synthetic or stainless steel wire. Mesh size, the number of openings per inch, determines the fineness of the material filtered.

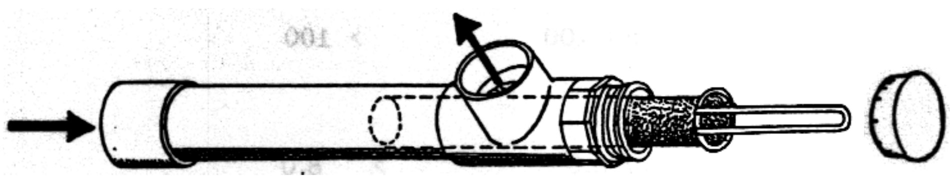

Figure 1. Screen Filter

Surface water sources should have a coarse screen filter installed on the pump inlet (suction) line to block trash and large debris. To avoid floating debris, the pump inlet should be located two feet below the water surface but suspended above the bottom.

Screen filters remove only small amounts of sands and organic material before clogging and causing a flow rate reduction. Two or more filters installed in parallel will increase the time between screen cleanings. Screen cleaning can be a manual or automatic operation.

Wafer (disc) filters consist of a stack of washers that provide a filtering surface area for the water to pass over as it flows through the filter (see Figure 2). These filters are sized based on the equivalent screen mesh filter size. They also require periodic cleaning. Some manufacturers provide an automatic backflush feature. Wafer filters provide more filter surface area than screen filters of the same size.

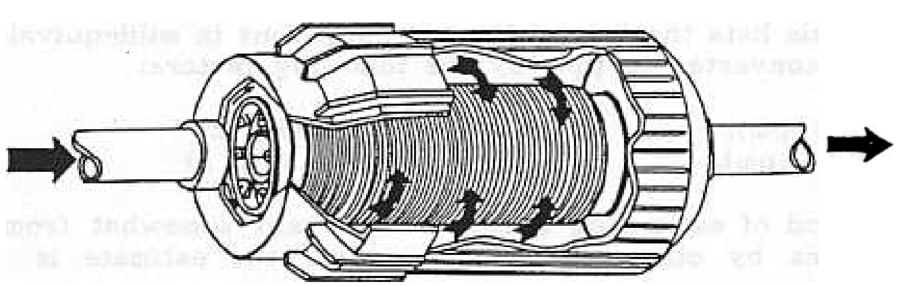

Figure 2. Wafer (disc) filter

Media (sand) filters are available with the capacity to efficiently remove most types of physical plugging sources (see Figure 3). These filters will remove colloidal and organic material usually present in surface waters. The size and type of media used determines the degree of filtration. The finer the media, the smaller the particle size that will be removed. Table 2 shows the relationship between sand grade and screen mesh size.

Table 2. Sand media size and screen mesh equivalents

Sand Number	Sand Diameter (in)	Sand Pore Diameter (in)	Screen Mesh
8	0.059	0.008	70
11	0.031	0.004	140
16	0.026	0.003	170
20	0.018	0.002	230
30	0.011	0.001	400

(after Fereres, 1981)

Size of the media filter required is determined by the flow rate of the system and is measured by the top surface area of the filter. These filters should normally be sized to provide a minimum of one square foot of top surface area for every 20 gallons per minute (GPM) of flow.

Filters are cleaned by reversing the direction of water flow through them; this procedure is call backwashing. Backwashing can be manual or automatic on a set time interval or at a specific pressure drop. When a media filter is in use, it should be installed with an additional screen filter (200-mesh or manufacturer's recommendation) downstream to prevent the transport of sand to the irrigation system during the backwash procedure.

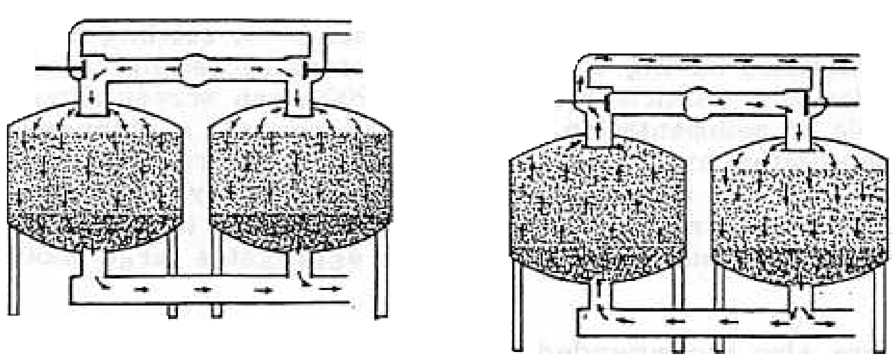

Figure 3. Sand filter

Vortex or centrifugal filters (Figure 4) effectively remove sand and larger particles but are not effective at removing algae, very fine precipitates and other light-weight materials. This type of filter should be used as the first filter if the water source is a sand-pumping well or a fast-moving stream. It should be followed by a media and screen filter for surface water sources or screen or wafer filter for well water.

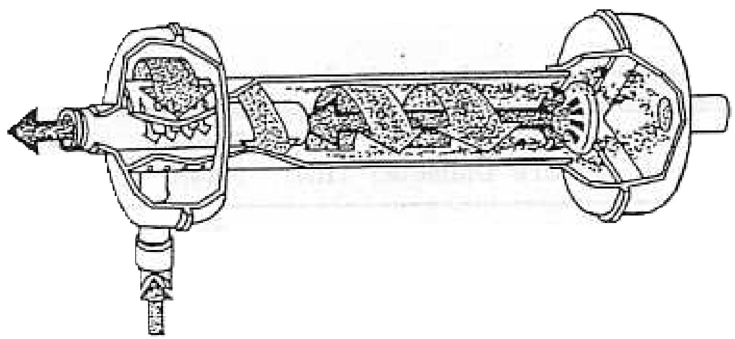

Figure 4. Vortex filter

Settling Ponds

In addition to filtration, the quality of water with high levels of solids can be improved with settling ponds or basins to remove large inorganic particles. Settling ponds can also be used for aeration of groundwater containing high amounts of iron or manganese.

Experiments have shown that a ferrous iron content as low as 0.2 ppm can contribute to iron deposition (Gilbert and Ford, 1986). Iron is very common in shallow wells in many parts of Florida, but it can often be economically removed from irrigation water by aeration (or by some other means of oxidation), followed by sedimentation and/or filtration.

Existing ponds can sometimes be used as settling basins. They need not be elaborate structures; however, settling basins should be accessible for cleaning and large enough that the velocity of the flowing water is sufficiently slow that particles can settle out. Experience based on municipal sedimentation basins indicates that the maximum velocity should be limited to 1 foot per second. A settling basin should be designed to remove particles having equivalent diameters exceeding 75 microns, which corresponds to the size of a particle removed by a 200-mesh screen filter. The basin works on the principle of sedimentation, which is the removal of suspended particles that are heavier than water by gravitational settling. Materials which are held in suspension due to the velocity of the water can be removed by lowering the velocity. In some cases, materials that are dissolved in solution oxidize (through exposure to a free air surface), precipitate, and flocculate to form aggregates large enough to settle out of the water.

Settling ponds are also recommended when the irrigation water source is a fast moving stream. Velocity of the water is slowed in the settling pond, thus allowing many particles to settle out.

Flushing

Regular flushing of drip irrigation pipelines to minimize sediment build up is recommended. Valves large enough to allow sufficient velocity of flow should be installed at the ends of mains, submains and manifolds. Also, allowances for flushing should be made at the ends of lateral lines. The flushing procedure should begin with the mains, followed by the submains, manifolds, and finally the laterals. Flushing should continue until clean water runs from the flushed line for at least two minutes. A regular maintenance program of inspection and flushing will help significantly in preventing emitter plugging. To avoid plugging problems when fertigating it is best to flush all fertilizer from the lateral lines prior to shutting the irrigation system down.

Chemical Treatment

Chemical treatment is often required to prevent emitter plugging due to microbial growth and/or mineral precipitation. The attachment of inorganic particles to microbial slime is a significant source of emitter plugging. Chlorination* is an effective measure against microbial activity (Ford; 1977, 1979a,b,c; Tyson and Harrison, 1985). Acid injection can remove scale deposits, reduce or eliminate mineral precipitation, and create an environment unsuitable for microbial growth (Cowan, 1976). *(Warning: Use chlorine and all other chemicals only according to label directions.) Bulk chemicals should be stored in a secure place following label directions.

Chlorine Injection

Chlorination is the most common method for treating bacterial slimes. If the microirrigation system water source is not chlorinated, it is a good practice to equip the system to inject chlorine to suppress microbial growth. Since bacteria can grow within filters, chlorine injection should occur prior to filtration.

Liquid sodium hypochlorite ($NaOCl$), the same formulation as laundry bleach, is about 5.25 percent chlorine. A 10 percent solution is often 2available and is usually more economical. It is the easiest form of chlorine to handle and is most often used in drip irrigation systems. Powdered calcium hypochlorite ($CaCOCl_2$), also called High Test Hypochlorite (HTH), is not recommended for injection into microirrigation systems since it can produce precipitates that can plug emitters, especially at high pH levels (Tyson and Harrison, 1985). Chlorine gas is <u>not</u> lableled at this time for use in irrigation systems in Florida.

The following are several possible chlorine injection schemes: 1) inject continuously at a low level to obtain detectable free chlorine at the ends of the laterals, 2) inject at intervals (once at the end of each irrigation cycle) at concentrations of 20 ppm for a duration long enough to reach the last emitter in the system, and 3) a slug treatment at high concentrations (50 ppm) weekly at the end of an irrigation cycle for a duration sufficient to distribute the chlorine through the entire piping system. The method used will depend on the growth potential of microbial organisms, the injection method and equipment, and the scheduling of injection of other chemicals. If sulfur slime is present a continuous chlorine treatment is recommended. Ford (1979c) developed a key which recommends chlorine injection rates for Florida conditions and irrigation systems.

The amount of liquid sodium hypochlorite required for injection into the irrigation water to supply a desired dosage in parts per million can be calculated by the following simplified method:

$$I = (0.006 \times P \times Q) / m \qquad \text{Eq. 4}$$

where,

I = gallons of liquid sodium hypochlorite injected per hour,
P = parts per million desired,
Q = system flow rate in gpm,
m = percent chlorine in the source, normally 5.25 % or 10 %.

For more detailed information on injection rates, volumes and durations the reader is referred to Clark et al. (1988).

When chlorine is injected, a test kit should be used to check to see that the injection rate is sufficient. Color test kits (D.P.D.) that measure 'free residual' chlorine, which is the primary bactericidal agent, should be used. The orthotolidine type test kit, which is often used to measure total chlorine content in swimming pools is not satisfactory for this purpose. Proper test kits can be purchased from irrigation equipment dealers. Check the water at the farthest outlet from the injection pump. There should be a residual chlorine concentration of 1-2 ppm at that point.

Chlorination for bacterial control is relatively ineffective if irrigation water pH is above 7.5, so acid additions may be necessary to lower the pH to increase the biocidal action of chlorine for more alkaline waters. This may be required when the water source is the Floridan aquifer.

Acid Treatment

Acid can be used to lower the pH of irrigation water to reduce the potential for chemical precipitation and to enhance the effectiveness of the chlorine injection. Sulfuric, hydrochloric and phosphoric acid are all used for this purpose (Kidder and Hanlon, 1985). Acid can be injected in much the same way as fertilizer, however extreme caution is required. The amount of acid to inject depends on the quantity of bases (buffering capacity) of the irrigation water and concentration of the acid to be injected. One milliequivalent of acid completely neutralizes one milliequivalent of bases.

If acid is injected on a continuous basis to prevent the formation of calcium and magnesium precipitates, the injection rate should be adjusted until the pH of the irrigation water is just below 7.0. If the intent of the acid injection is to remove existing scale buildup within the microirrigation system, the pH will have to be lowered further (Cowen and Weintritt, 1976). The release of water into the soil should be minimized during this process since plant root damage is possible. An acid slug should be injected into the irrigation system and allowed to remain in the system for several hours, after which the system should be flushed with water. Acid is most effective at preventing and dissolving alkaline scale. Caution is advised to avoid concentrations that may be harmful to emitters and other system components.

Phosphoric acid can be used for water treatment, and it is also a fertilizer source. Some microirrigation system operators use phosphoric acid in their fertilizer mixes. Caution is advised if phosphoric acid is used to suppress microbial growth. Care should be used with the injection of phosphoric acid into hard water since it may cause the mineral precipitation at the interface between the injected chemical and the water source. Irrigation system flow rates should be closely monitored, and action taken (chlorination) if flow rates decline. Some fertilizer companies are blending sulfuric acid with their liquid fertilizer to reduce pH and minimize plugging potential. More information is needed on the benefits of this practice.

For safety it is advisable to dilute the concentrated acid in a non-metal acid-resistant mixing tank prior to injection into the irrigation system. The acid injection point should be beyond any metal connections or filters to avoid corrosion. Flushing the injection system with water after the acid application is a good practice to avoid deterioration of components in direct contact with the acid.

Acids and chlorine compounds should be stored separately, preferably in epoxy-coated plastic or fiberglass storage tanks. Acid can react with hypochlorite to produce chlorine gas and heat; therefore, the injection of acid should be done at some distance prior to the injection of chlorine to allow proper mixing of the acid with the irrigation water before it encounters the chlorine. Hydrochloric, sulfuric and phosphoric acids are all highly toxic. Always wear goggles and chemical resistant clothing whenever handling these acids. Acid must be poured into water; never pour water into acid.

Scale Inhibitors

Scale inhibitors, such as chelating and sequestering agents, have long been used by other industries. Presently, a number of different chemicals are being marketed for use in microirrigation systems to prevent plugging. Many of these products contain some form of inorganic polyphosphate that can reduce or prevent precipitation of certain scale-forming minerals. Typically, these inorganic phosphates do not stop mineral precipitation, but keep it in the sub-microscopic range by inhibiting its growth. Probably the most commonly used of these materials is sodium hexametaphosphate - as little as 2 ppm can hold as much as 200 ppm calcium bicarbonate in solution (Cowan and Weintritt, 1976).

Sodium hexametaphosphate is not only effective against alkaline scale, but also forms complexes with iron and manganese and can prevent depositions of these materials. Although the amount of phosphate required to prevent iron deposits depends on several factors, a general recommendation is 2-4 ppm phosphate for each ppm of iron or manganese (Cowen and Weintritt, 1976). These phosphates are relatively inexpensive, readily soluble in water, nontoxic, and effective at low injection rates.

Pond Treatment

Algae problems, which often occur with surface water sources such as a pond, can be effectively treated with copper sulfate ($CuSO_4$). Dosages of 1 to 2 ppm (1.4 to 2.7 pounds per acre foot) are sufficient and safe to treat algae growth. Copper sulfate should be applied when the pond water temperature is above 60 F. Treatments may be repeated at 2 to 4-week intervals depending on the biological activity in the pond. Copper sulfate should be mixed into the pond (i.e., sprinkled into the wake of a boat). The distribution of biocides into surface water must be in compliance with EPA regulations.

Copper sulfate can be harmful to fish if alkalinity, a measure of the water's capacity to neutralize acid, is low. Alkalinity is measured volumetrically by titration with H_2SO_4 and is reported in terms of equivalent $CaCO_3$. Table 3 provides a reference for determining copper sulfate rate to add given different alkalinity levels. Repeated use of copper sulfate can result in the build to toxic levels for plants.

Table 3. Copper Sulfate ($CuSO_4$) Levels Safe for Fish

Alkalinity Value ($CaCO_3$, mg/l)	Addition of Copper Sulfate
below 40	do not use
40-60	1.0 lb per acre-ft of water
60-100	1.3 lb per acre-ft of water
over 100	2.7 lb per acre-ft of water

(1 ppm = 2.7 lb per acre-ft)
(Dupress and Huner, 1984)

SUMMARY

1 Emitter plugging can occur from physical, biological and chemical causes.

2) A water quality analysis is vital to the proper design and operation of the microirrigation system.

3) Every microirrigation system needs some method of filtration.

4) Regular flushing of the lateral and main lines will help to prevent plugging.

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