Filtration, Treatment, and Maintenance Considerations for Micro-Irrigation Systems

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Micro-irrigation systems can deliver water and nutrients in precise amounts and at controlled frequencies directly to the plant's root zone. With micro-irrigation systems, an extensive network of pipe is used to distribute water to emitters that discharge it in droplets, small streams, or through mini-sprayers. The major cause of failure in micro-irrigation systems is emitter plugging. Emitter plugging can severely degrade irrigation system performance and application uniformity. Because the emitters are small and can easily plug, it is important to understand the filtration and maintenance requirements of these systems and be proactive to prevent plugging. The basic components of a typical micro-irrigation system are shown in Figure 1.

Causes and Prevention of Emitter Plugging

Plugging hazards for micro-irrigation systems fall into three general categories: physical (sediment), biological or organic (bacteria and algae), and chemical (scale). Frequently, plugging is caused by a combination of these factors. The type of emitter plugging problems will vary with the source of the irrigation water. Water sources can be grouped into two categories: surface and ground water. Each of these water sources is likely to present specific plugging hazards.

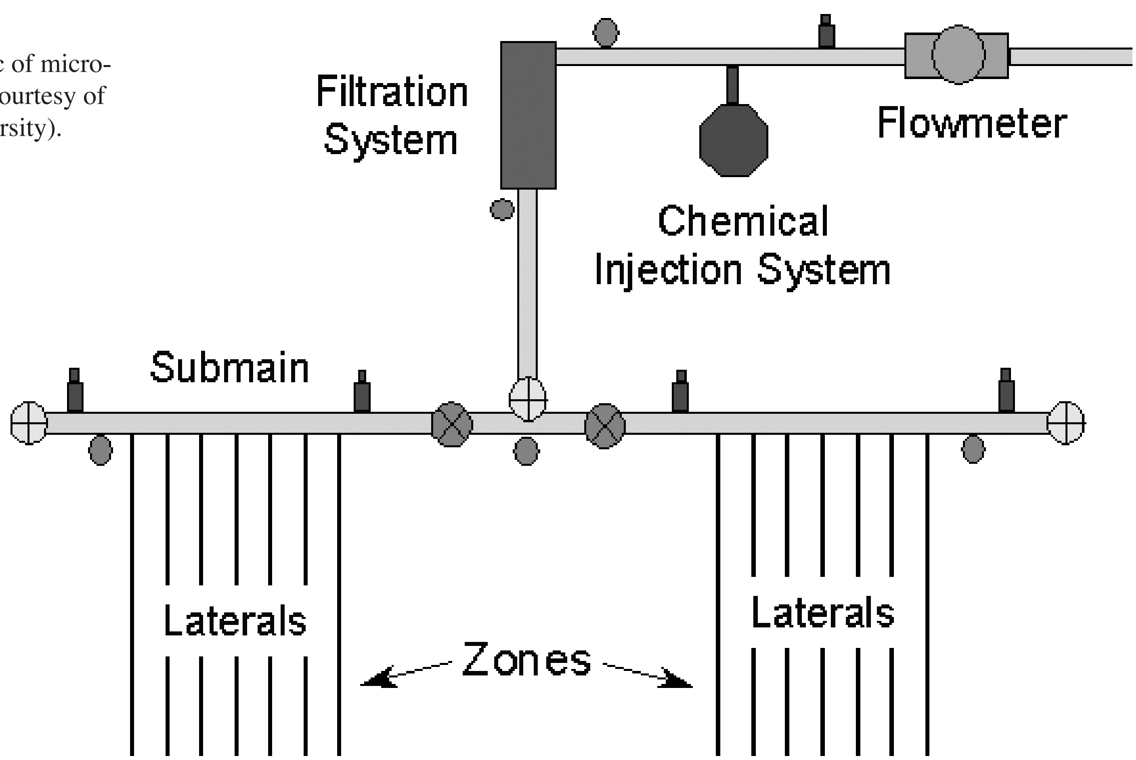

Figure 1. Schematic of micro-irrigation system (courtesy of Kansas State University).

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Water Quality Analysis

The quality of the irrigation water will determine, in part, the filtration, maintenance, and water treatment measures that are required to prevent emitter plugging and maintain good system performance. The emitter characteristics, in particular the size of the emitter opening, also play a part.

When analyzing water for potential use in a micro-irrigation system, the analysis should include the constituents listed in Table 1. If the source is ground water from a relatively deep, properly constructed well (> 100 ft), the bacterial population analysis may be omitted. If the source is surface water, hydrogen sulfide will not be present and can be omitted. Table 1 provides concentration levels for evaluating water quality in terms of emitter plugging potential.

Table 1. Criteria for evaluating the "plugging potential" of micro-irrigation water sources.

	Plugging hazard based on concentration		
Factor	**Slight**	**Moderate**	**Severe**
Physical			
Suspended solids (filterable)[a]	< 50	50 - 100	> 100
Chemical			
pH	< 7.0	7.0 – 7.5	> 7.5
Dissolved solids[a]	< 500	500 – 2,000	> 2,000
Manganese[a]	< 0.1	0.1 – 1.5	> 1.5
Iron[a]	< 0.1	0.1 – 1.5	> 1.5
Hydrogen sulfide[a]	< 0.2	0.2 – 2.0	> 2.0
Hardness[b]	< 150	150 – 300	> 300
Biological			
Bacteria population[c]	< 10,000	10,000 – 50,000	> 50,000

[a]maximum measured concentration from a representative sample (ppm),
[b]hardness as ppm $CaCO_3$,
[c]colony forming units per 100 ml

Two of the plugging hazards listed in Table 1 may be reported in units different from those shown in Table 1. The concentration, or level, of dissolved solids in a water sample can be measured by how the sample conducts electricity. A water quality analysis will sometimes report electrical conductivity (EC), usually in units of micromhos per centimeter (μmho/cm). To estimate parts per million (ppm) of dissolved solids as shown in Table 1, multiply the EC reading in μmho/cm by 0.64. For example, if the report indicates an EC of 1000 μmho/cm, then the dissolved solids concentration is approximately 640 ppm. Instead of ppm, concentration is some times reported in mg/L (milligrams per liter). Note that 1 ppm equals 1 mg/L.

The "hardness" of a particular water source is primarily related to concentrations of dissolved calcium (Ca) and magnesium (Mg), and is another indicator of its plugging potential. If Ca and Mg are each given in ppm or mg/L rather than hardness, hardness can be estimated by using:

$$Hardness = (2.5 \times Ca) + (4.1 \times Mg)$$

where: Ca and Mg concentrations are reported in mg/L or ppm.

If the analysis reports hardness in grains per gallon, one grain per gallon of hardness equals 17.1 ppm of hardness as $CaCO_3$.

Physical plugging hazards

Sources of physical plugging include sand and other suspended solids that are too large to pass through emitter openings. As was mentioned earlier, the characteristics of the emitter, particularly the size of the emitter opening, play a major role in the selection of the filtration system. Sand particles, which are capable of plugging emitters, are often pumped from wells. Water containing some suspended solids may be used with micro-irrigation systems if these suspended solids consist of silt and clay-sized particles, and if flocculation (combining of individual particles to form larger particles) does not occur. Research has shown that using water with suspended solids concentrations of as high as 500 ppm did not cause emitter plugging as long as the larger particles were filtered. If the water source contains a large amount of silt, or is a fast-moving stream, a settling basin may be required. In a settling basin, the velocity of the water is slowed thus allowing many particles to settle out.

Screen Filters

Constituents like suspended solids and sand are often removed using screen filters. Sizing of screen filters is based on the maximum particle size allowable by the emitter, the quality of the irrigation water, the flow volume between required cleanings, and the allowable pressure drop across the filter. Information about the maximum allowable particle size should be available from the emitter manufacturer. If not, a conservative rule of thumb is to remove any particles larger than one-tenth the diameter of the smallest opening in the emitter. Filtering particles equivalent to one-tenth the diameter of the smallest opening and larger prevents “bridging.” Bridging is a phenomenon where small particles can join together and plug an emitter by forming a “bridge” across the emitter opening. Table 2 shows the standard classification of soil particulate size ranges and the corresponding screen mesh numbers. A 200-mesh screen that has an opening size of 0.003 inches will remove particles the size of fine sand and larger and is usually adequate for micro-irrigation systems using ground water.

Flow rates through screen filters should not exceed 200 gallons per minute per square foot (gpm/ft^2) of effective filter area. The effective filter area is defined as the combined area of the openings in the filter screen. Filter manufacturers can supply you with effective filter area values for their products. Screen filters should be cleaned (backflushed) when the pressure drop across the filter increases by 3 to 5 psi (pounds per square inch) or as recommended by the manufacturer. Automatic backflushing is available on some screen filter systems. Screen filters can be cleaned manually by removing the screen and washing it with clean water. Figure 2 shows a typical screen filter.

Figure 2. Flushable screen filter (courtesy Yardney Water Management Systems, Inc.).

Sand Separators

In some applications where the water contains a large amount of sand, a sand separator may be required (Figure 3). Sand separators swirl the water using centrifugal action to separate sand and other heavy particles from the water. Properly functioning sand separators can remove 70 to 95% of heavy particles with equivalent diameters greater than 0.003 inches. If required, sand separators should be installed upstream of any filtration unit.

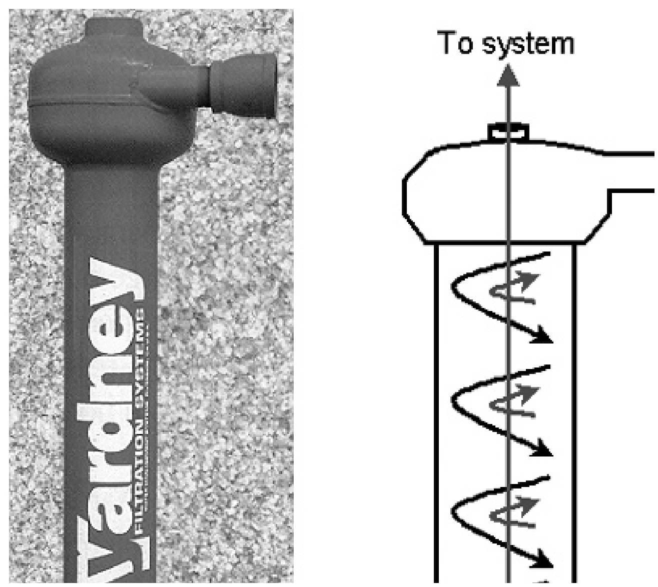

Figure 3. Sand separator (photo courtesy of Yardney Water Management Systems, Inc.)

Table 2. Classification of soils by particle size, with corresponding screen mesh numbers.[1]

Soil Classification	mm	Particle size microns	in.	Screen mesh number
Very coarse sand	1.00 – 2.00	1000 – 2000	0.0393 – 0.0786	18 –10
Course sand	0.50 – 1.00	500 – 1000	0.0197 – 0.0393	35 – 18
Medium sand	0.25 – 0.50	250 – 500	0.0098 – 0.0197	60 – 35
Fine sand	0.10 – 0.25	100 – 250	0.0039 – 0.0098	160 – 60
Very fine sand	0.05 – 0.10	50 – 100	0.0020 – 0.0039	270 – 160
Silt	0.002 – 0.05	2 – 50	0.00008 – 0.0020	400 – 270[2]
Clay[3]	<0.002	<2	<0.00008	–

[1]From Keller and Bliesner
[2]400 mesh screen has the smallest opening, approx. 0.03 mm.
[3]Not visible to the eye. Individual bacteria and viruses are smaller than clay particles.

Biological plugging hazards

Individual bacteria and algae cells, and their organic residues are often small enough to pass through the filters of an irrigation system. Once in the system, this material can form aggregates that plug emitters. Additionally, a micro-irrigation system can provide a favorable environment for bacterial growth. Residues of decomposing algae and bacteria can accumulate in pipes and emitters and support the growth of slime-forming bacteria. The resulting slime can plug emitters.

In addition to bacteria and algae, surface water can also contain larger organic material such as moss, snails, and plant residue that must be adequately filtered to avoid plugging problems. To remove larger material, coarse mesh screens are generally required on the pump intake. When surface water is used for irrigation, more refined filtration systems like media or disc filters are often required.

Media Filters

Media filters (Figure 4) are excellent for removing bacterial slimes and algae. The depth of the media provides a 3-dimensional screening-like process that has much greater debris storage capability and capacity than screen filters. Some examples of filter media are shown in Table 3. The mean effective media size is an indicator of particle size that will be removed by the filter. The quality of filtration increases with smaller mean effective media size (larger screen mesh size equivalents correspond to the filtration of smaller particles).

Flow rates for media filters should not exceed approximately 25 gpm per square foot of filter surface area. The filter surface area is simply the sum of the areas of the filter media surface in the media tanks. In most installations, multiple media filter units (3 or more) are necessary to accommodate backflushing while the irrigation system continues to operate. If fewer units are used, flow rate limits can be exceeded during backflushing. Even if backflushing is performed when not irrigating, at least two filters are necessary in order to provide clean (filtered) water to the filter being backflushed. Media filters should be backflushed when the pressure drop across the filter reaches about 10 psi or as recommended by the manufacturer. To reduce the need for frequent backflushing, lower flow rates should be used when the water source contains greater than 100 ppm of suspended solids.

Backflush flow rates depend on the media particle size; lower flow rates should be used for finer filter media to

Table 3. Media size and screen mesh equivalent.

Media No.	Material	Mean effective media size mm	in.	Screen mesh size
8	crushed granite	1.50	0.059	100 – 140
11	crushed granite	0.78	0.031	140 – 200
16	crushed silica	0.66	0.026	140 – 200
20	crushed silica	0.46	0.018	200 – 230
30	crushed silica	0.34	0.013	230 – 400

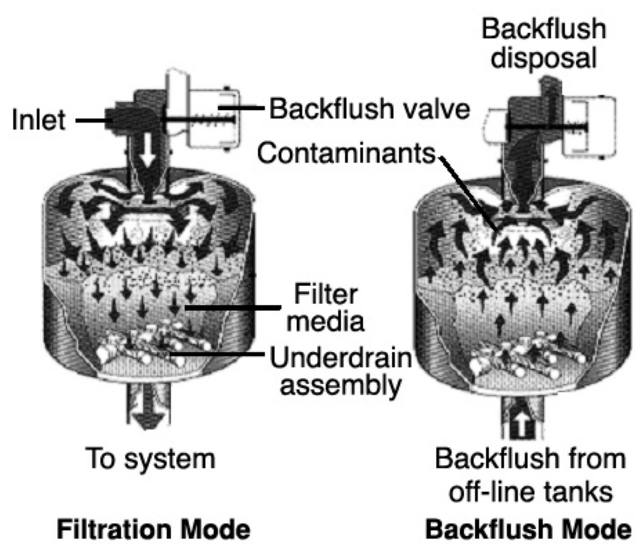

Figure 4. Photo and schematic of sand media filter (photo courtesy of Waterman Industries, schematic adapted from Claude Laval Corp.).

prevent the media from being washed out of the filter. Automatic backflushing is often used on media filtration systems. Most manufacturers recommend the use of a screen filter downstream from the media filter to keep escaping filter media from plugging emitters.

Disc Filters

Disc filters (Figure 5) are sometimes used to remove biological material from irrigation water. Disc filters are a hybrid of screen and media filters. Microscopic grooves between discs (normally plastic) catch and hold unwanted material until it is removed by backflushing. During backflushing, the discs within the filters separate and are cleaned. Disc filters require less water than media filters for backflushing, but they may require backflushing pressures as high as 50 psi. Such high pressures may require the use of a pressure-sustaining valve, booster pump, or both. A typical recommended flow rate for filtering ground water with 200-mesh equivalent disk filter is 50 gpm/ft^2 of filter area.

If sand is a particular concern for a given system, one may choose to avoid using disc filters entirely. During backflushing, when the discs are separated, sand may become lodged between discs. If this happens, the effective mesh size of the filter is reduced and filtration will be less effective. If sand is an issue, consider using a media filter. If a disc filter is used, consider installing a sand separator before the disc filter unit.

A summary of the typical application, and the advantages and disadvantages of the various filter types discussed here are presented in Table 4

Figure 5. Photo and schematic of disc filter (schematic courtesy of Arkal Filtration Systems).

Table 4. Comparison of filter types.

Filter type	Application	Advantages	Disadvantages
Sand Separator	Use if well pumps sand or water source is fast moving stream.	No moving parts. Removes 70 to 95% of particles larger than medium sand.	Will not remove particles smaller than fine sand.
Screen	Use when primary plugging hazard is physical (suspended solids).	Relatively inexpensive. Well suited to systems using ground water	Less expensive designs require manual cleaning.
Media	Used to filter both physical and biological material.	3-dimensional filtering. Larger capacity than screen. filter.	Not well suited to low flow systems (< 25 to 50 gpm). Most applications require multiple media tanks.
Disc	Used to filter both physical and biological material.	Batteries of parallel filters will accommodate high flow systems.	High pressure needed during automated backflushing. Booster pump may be required. Not suited to applications where sand is significant plugging hazard.

Water Treatment to Prevent Biological Plugging

Chlorine is commonly injected into a micro-irrigation system to eliminate any unfiltered biological material. If the biological load of the irrigation water is severe (Table 1), a low concentration (1 to 2 ppm) of chlorine should be injected continuously. If the biological load is slight to moderate, and thus the potential for biological plugging is low, a periodic chlorine shock treatment may be used as an alternative to continuous chlorine injection. A typical chlorine shock treatment uses a concentration of 10 to 30 ppm. Sodium hypochlorite (NaOCl) or liquid bleach is a safe and easily obtained chlorine source. However, it degrades over time so it should not be stored for long periods before using.

Liquid bleach is about 5 percent chlorine. A 20 ppm chlorine shock treatment for an irrigation system with a capacity of 500 gpm would require approximately 11 gallons of chlorine per hour or about one-fifth of a gallon of bleach per minute. For systems that utilize ground water, a semiannual chlorine shock treatment will likely be sufficient to prevent biological plugging. The frequency of shock treatments is not, however, set in stone. One should continuously monitor system performance and adjust the water treatment and maintenance schedule as needed.

With micro-irrigation systems, if the pH of the water is high, concurrent acidification and chlorination may be required. Chlorination is relatively ineffective for bacterial control if the pH of the water is above 7.5, so adding acid may be necessary to lower the pH and increase the biocidal action of the chlorine. Acid and chlorine injection points should be at least 2 to 3 feet apart. Acid and chlorine should **never** be combined in the same container because dangerous chlorine gas is released.

When chlorine is injected, a test kit should be used to ensure that the injection rate is adequate. A D.P.D. type (N,N-Diethyl-p-Phenylenediamine) color test that measures the "free residual" chlorine should be used. The Hach Company, among others, makes D.P.D test kits. Common test kits that one might use to measure the total chlorine content of a swimming pool (orthototlidine-type) are not satisfactory for irrigation applications. To ensure the system is adequately treated, the chlorine concentration at the flush outlet farthest from the injection pump should equal the desired treatment concentration.

As was mentioned above, most biological plugging hazards are associated with surface water; however, very small concentrations of iron (0.1 – 0.3 ppm) in ground water can pose a biological plugging threat. Certain bacteria can use iron as an energy source. Those bacteria oxidize ferrous iron (+2 charge) to form ferric (+3 charge) iron. As the bacteria grow, they form slimy masses of cells called ochre that may combine with other materials and clog emitters. As with other biological plugging hazards, if iron bacteria do develop, chlorine injections can be used to kill the bacteria. The dead bacteria can then be flushed from the system.

While chlorine injections are effective against biological plugging hazards, injecting chlorine has no effect on scale deposits. There are other commercial materials to dislodge and dissolve scale deposits.

Chemical plugging hazards

In Virginia, chemical precipitation (scale formation) is not normally a problem when using surface water. Ground water, however, often contains high levels of dissolved minerals that can, given the right conditions, precipitate and form scale that can plug emitters.

Calcium Carbonate

Two major chemical plugging hazards for micro-irrigation systems are precipitation of calcium carbonate ($CaCO_3$), also called lime or scale, and the formation of iron precipitates. Precipitation of $CaCO_3$ can occur in one of two ways: evaporation of water leaving the salts behind, or a change in solubility due to changes in solution characteristics (mainly temperature or pH). An increase in either pH or temperature reduces the solubility of calcium in water and can result in precipitation of $CaCO_3$. In many cases, bicarbonate (HCO_3) may be present in the irrigation water. Bicarbonate can react with naturally occurring calcium in the water to form scale deposits.

Continuous acid injection is often used to lower the water's pH (< 7.0) and decrease the possibility of $CaCO_3$ precipitation. Sulfuric, hydrochloric, and phosphoric acid can be used for this purpose. If the intent of the acid injection is to remove existing scale buildup within the irrigation system, the pH will have to be lowered further, as low as pH = 2. When removing existing scale deposits, the release of low pH water into the soil should be minimized as root damage may occur. An acid slug (i.e., a concentrated dose) should be injected into the irrigation system and remain in the system for several hours before the system is flushed with irrigation water. Although acid will not normally corrode PVC (polyvinyl chloride) and PE (polyethylene) tubing, it may be corrosive to steel and aluminum.

Iron

In addition to the biological oxidation of iron and the associated plugging hazards mentioned previously, iron can also be chemically oxidized (rusted). The oxidized (ferric) iron can form precipitates that plug emitters. If iron presents a problem in your operation, there are two common treatment options. The first is to pump the ground water into a reservoir before pumping it into the irrigation system, making sure adequate aeration occurs in the reservoir. The ferrous iron is oxidized and the ferric iron settles out. The second option is to inject a strong oxidizing agent upstream of the filter. The resulting ferric iron is then filtered before it enters the laterals. Chlorine can be used to oxidize ferrous iron.

Flushing

To minimize the buildup of sediment and organic residues, regular flushing of micro-irrigation systems is recommended. The system should be designed such that the mainline, laterals and valves are sized to permit a sufficient flushing velocity (≥ 1 ft/sec). Flush valves should be installed at the end of mains, submains, and flushlines (if present). If dedicated flushlines that connect the downstream ends of the laterals are not installed, provisions should be made for flushing individual laterals. Begin the flushing procedure with the system mains and then proceed through the system finishing with 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.

Injecting chemicals into Micro-irrigation system

When injecting chemicals or fertilizers into an irrigation system, an appropriate backflow prevention device that conforms to the standards set by the American Society of Agricultural Engineers (ASAE, 2001) should be installed to ensure that the water source does not become contaminated. A backflow prevention device should include the following components:

- A check valve located upstream from the chemical injection point to prevent the flow of a mixture of water and/or chemicals in the opposite direction of that intended,
- A low-pressure drain to prevent seepage past the check valve,
- A vacuum relief valve to ensure a siphon (back-suction) cannot develop, and
- A check valve on the chemical injection line to prevent water from flowing into the chemical storage tank.

If an externally-powered metering pump is used for chemical injection, it should be electrically interlocked with the irrigation pump. This interlock should prevent the injection pump from operating unless the irrigation pump is operating. A second interlock should be installed to ensure that if flow in the chemical injection line ceases the irrigation pump is shut down.

Depending on local regulations, more extensive backflow prevention measures may be required. In addition, when chemicals are injected into an irrigation system, certain certifications may be required. Check with your local Virginia Cooperative Extension Office.

As a general rule, all chemicals should be injected upstream from the irrigation system's filtration unit.

Before injecting any chemical, or before mixing any chemicals, one should always perform a "jar test" to evaluate potential plugging hazards.

1. Add drops of the chemical to be injected into a sample of the irrigation water so that the concentration is equivalent to the solution that would be in the system.
2. Cover and place the mixture in a dark, cool environment for at least 12 hours.
3. Direct a light beam at the bottom of the sample container to determine if any precipitates have formed. If no apparent precipitates have formed, the chemical will normally be safe to use with that specific water source.

To avoid plugging problems when fertigating, flush all fertilizer from the laterals prior to shutting the irrigation system down.

Summary

When using micro-irrigation, emitter plugging can occur from physical, biological, and chemical causes. It is important to prevent plugging problems before they occur. The best prevention plan includes an effective filtration, water treatment, and maintenance strategy. A water analysis is vital to the proper design and operation of the micro-irrigation system.

To assess irrigation system performance and to ensure that components like filters are working correctly, flow meters and pressure gauges must be properly installed to provide feedback to the system operator. Monitoring flow meters and pressure gauges over time can reveal system performance anomalies that may require attention.

Filtration equipment may be the single item of greatest cost when installing a micro-irrigation system. One must resist the temptation to "cut corners." Good filtration will pay for itself by avoiding the costs and extra effort required to repair a damaged system.

No matter how well designed your filtration system is, some "contaminants" will find their way into the system. To prevent the accumulation of those contaminants and the resulting emitter plugging, flush the system periodically. Regular flushing is critical to system health and longevity.

If the micro-irrigation system is equipped with a method for chemically treating the water source (most will be), backflow protection, and other safety provisions, are necessary.

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