TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE

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WATER QUALITY TESTING FOR MICRO IRRIGATION SYSTEMS

INTRODUCTION

Water quality is usually the most important consideration when determining whether a micro irrigation system is feasible. Micro-irrigation water may come from many sources in Washington, including: wells, reservoirs, and rivers. Each source has unique water quality characteristics that can be broken down into three categories: chemical, physical, and biological. These characteristics have the potential to negatively affect the components of a micro irrigation system. A Water Quality analysis should identify most of the adverse characteristics of the micro-irrigation source water.

WATER QUALITY ANALYSIS

It is recommended to test water quality for:

- *Electrical Conductivity (EC)*, a measure of total salinity or total dissolved solids (TDS)
- *pH*, a measure of acidity
- *Cations*: Sodium (Na), Calcium (Ca), and Magnesium (Mg)
- *Anions*: Carbonate (CO3), Bicarbonate (HCO3), Sulfate (SO4), and Chloride (Cl)
- *Nitrate Nitrogen* (NO3) and *Potassium* (K)
- *Sodium Absorption Ratio (SAR)*, a measure of the potential for sodium in the water
- *Zinc* (Zn), *Iron* (Fe), *Copper* (Cu), *Boron* (B), *Manganese* (Mn), and *Total Phosphorus* (P)

Additional analysis may need to be considered based on locality for:

- *Electrical Conductivity (EC)*, a measure of total salinity or total dissolved solids
- *Total suspended solids*, a measure of particles in suspension
- *Bacterial Population*, a measure or count of bacterial presence
- *Presence of Oil*

These locality concerns may attribute to excessive filter and emitter clogging.

WATER QUALITY CONCERNS

The two primary water quality concerns for micro-irrigation systems are the emitter plugging potential and the chemical effect of water on plant production.

Well and surface water sources often contain high concentrations of undesirable minerals and chemicals. Surface water can contain organic debris such as: algae, moss, bacteria, soil particles, etc. Well water may also contain sand and bacteria. These contaminants are the main contributors to poor micro-irrigation water quality.

PLUGGING POTENTIAL

The first primary water quality concern for micro irrigation systems are the plugging potential. The plugging potential of the water can be a result of physical, chemical, or biological characteristics of the water. Plugging of system components (primarily emitters and filters) is the main cause of micro-irrigation system failure.

In general; physical factors can be controlled by filtration of the water, chemical factors can be controlled by the adjustment of pH using acid injection into the water, and biological factors can be controlled by chlorine injection into the water. **Table 1** lists some of the agents of micro-irrigation system plugging.

A water quality test can identify potential plugging problems resident in the irrigation water source that may be treated by physical and/or chemical measures.

Table 1 Physical, chemical, and biological factors causing plugging of emitters 1

Physical	Chemical	Biological
Organic debris	Ca or Mg carbonates, Calcium sulfate, Ferric iron,	Filaments
Aquatic weeds, Moss, Algae	Manganese, Iron, Zinc, Copper	Slimes
		Microbial deposits
Aquatic creatures,	Metal hydroxides, carbonates,	
Snails, Fish	silicates and sulfides	Iron ochre
Soil particles, sand, silt, clay	Fertilizers, phosphates, ammonias	Manganese ochre
		Sulfur ochre
Plastic particles	Herbicides, Pesticides	

1/ Adapted from Table 6-11, NEH, Part 652, Irrigation Guide, Chapter 6, Irrigation System Design

Table 2 Plugging potential of irrigation water used in micro irrigation systems

Potential Problem	Low	Medium	Severe
Physical			
• Suspended solids, ppm	< 50	50 -100	> 100
Chemical			
• pH	< 7.0	7.0 – 8.0	> 8.0
• TDS, ppm	< 500	500 – 2,000	> 2,000
• Manganese, ppm	< 0.1	0.1 – 1.5	> 1.5
• Iron, ppm	< 0.1	0.1 – 1.5	> 1.5
• Hydrogen sulfide, ppm	< 0.5	0.5 – 2.0	> 2.0
Biological			
• Bacteria population - no. per mL 1/	< 10,000	10,000 – 50,000	> 50,000

1/ Bacteria populations reflect increased algae and microbial nutrients.

Table 2 lists the potential water quality problems and rates the severity of the plugging potential for micro-irrigation systems. Micro-irrigation water with a low concern requires little or no special treatment. A medium concern requires special attention and periodic treatment. Micro-irrigation water with several medium concerns will usually require constant treatment.

A severe concern requires constant treatment or the micro-irrigation system is likely to fail.

CHEMICAL PRECIPITATION

Chemical precipitation may occur during a chemical reaction in which solid particles fall out of a liquid solution. These solid particles may potentially plug the micro-irrigation system. Subsurface micro-irrigation systems have an advantage over surface drip systems because the emitters in the driplines are below ground and buffered from sunlight and temperature. These elements could encourage both biological and chemical activity causing chemical precipitation.

Water pH and temperature also play a major role in many reactions. Several important chemical precipitation hazards are summarized in **Table 3.** Plugging hazards and their treatment options are shown in **Table 4.**

Table 3 Notes on Chemical Clogging Hazards 1/

1. Bicarbonate concentrations exceeding about 2 meq/L and pH exceeding about 7.5 can cause calcium carbonate precipitation.
2. Calcium concentrations exceeding 2 to 3 meq/L can cause precipitates to form during injection of some phosphate fertilizers. Special procedures are necessary for the injection of phosphate fertilizers, and careful injection should be attempted only by experienced personnel.
3. High concentrations of sulfide ions can cause iron and manganese precipitation. Iron and manganese sulfides are very insoluble, even in acid solutions. In this case, frequent acidification or the use of a settling basin for separating iron and manganese precipitants is advisable.
4. Irrigation water containing more than 0.1 ppm sulfides may encourage growth of sulfur bacteria within the irrigation system. Regular chlorination may be needed.
5. Chlorination when manganese is present should be used with caution, as a reaction time delay may occur between chlorination and the development of the precipitate. This may cause the manganese precipitate to form downstream of the filter and cause emitter clogging.

1/ Rogers, Danny H. ,Freddie R. Lamm, and Mahbub Alam, *SDI Water Quality Assessment Guideline*, MF-2575, Kansas State University, July 2003.

Table 4 Water Treatments to Prevent Plugging in Micro-Irrigation Systems

Problem	Treatment Options
Carbonate Precipitate (white precipitate) HCO_3 greater than 2.0meq/l and pH > 7.5	**1.** Continuous injection: maintain pH between 5 and 7 **2.** Periodic injection: maintain pH at under 4 for 30-60 minutes daily.
Iron Precipitate (reddish precipitate) Fe concentrations greater than 0.1 ppm	**1.** Aeration and settling to oxidize iron. (Best treatment for high concentrations: 10 ppm pr more). **2.** Chlorine precipitation- injecting chlorine to precipitate iron: A. Use an injection rate of 1 ppm of chlorine per 0.7 ppm of iron. B. Inject in front of the filter so that the precipitate is filtered out. **3.** Reduce pH to 4 or less for 30-60 minutes daily
Manganese Precipitate (black precipitate) Mn concentrations greater than 0.1 ppm	**1.** Inject 1 ppm of chlorine per 1.3 ppm of manganese in front of the filter.
Iron bacteria (reddish slime) Iron concentrations greater than 0.1 ppm	**1.** Inject chlorine at a rate of 1 ppm free chlorine continuously or 10 to 20 ppm for 30 to 60 minutes
Sulfur bacteria (white cottony slime) sulfide concentrations greater than 0.1 ppm	**1.** Inject chlorine continuously at a rate of 1 ppm per 4 to 8 ppm of hydrogen sulfide, or **2.** Inject chlorine intermittently at 1 ppm free chlorine or 30 to 60 minutes daily.
Bacterial slime and algae	**1.** Inject chlorine at a rate of 0.5 to 1 ppm continuously or 2 ppm for 20 minutes at the end of each irrigation
Iron sulfide (black sand-like material) Iron and sulfide concentrations greater than 0.1 ppm	**1.** Dissolve iron by injecting acid continuously to lower pH to between 5 and 7.

Rogers, Danny H. ,Freddie R. Lamm, and Mahbub Alam, *SDI Water Quality Assessment Guideline*, MF-2575, Kansas State

EFFECT OF WATER QUALITY ON PLANT PRODUCTION

The second primary water quality concern for micro irrigation systems is the chemical effect of the water on plant production. Water high in dissolved chemicals and minerals affects plant uptake and growth, reducing potential yields and production. Trace elements can also affect sensitive crops, even at very low concentrations.

Suitability of water for micro-irrigation crop production depends on the total amount and type of salts, ions, and other elements in the water. Other considerations such as crops grown, irrigation water management, cultural practices, and climate factors should be evaluated for use with a micro-irrigation system. Guidelines for evaluating water quality for irrigation are given in **Table 5**. These guidelines are limited to water quality parameters that are normally encountered and that materially affect crop production. **Table 6** lists the maximum recommended concentration of trace elements in irrigation water.

SALINITY AND SODICITY

Salinity and Sodicity are the primary cause of yield reduction of irrigated crops due to water quality. Salinity is a measure of sodium chloride and sodicity is a measure of sodium present in the water. If the total quantity of salinity or sodicity in the irrigation water is high enough salts may accumulate in the crop root zone or on the plant to the extent that crop growth and yield are affected.

Where excessive soluble salts accumulate in the root zone, plants have increasing difficulty in extracting water from the soil profile. Reduced water uptake by the plant can result in slow or reduced growth. This can cause the appearance of a drought condition (i.e., plant wilting) even with relative high soil moisture conditions. Crops have different salinity and sodicity tolerance levels and effects of salinity and sodicity can vary with growth stage. Tolerance to salinity or sodicity can be very low at germination and small seedling stage, but usually increases as the plant grows and matures.

Additional information and details on effects of specific ions are provided in the National Engineering Handbook (NEH), Part 623, Chapter 2, Irrigation Water Requirements. Also see American Society of Civil Engineers (ASCE) Report 71, Agricultural Salinity Assessment and Management.

HOW TO GET A WATER SAMPLE

Water analyses can only be accurate if the sample is taken correctly. Please use the following guidelines when collecting a well water sample for irrigation water quality analysis.

Containers: Samples should be collected in a clean, plastic bottle with a screw cap. Thoroughly wash bottles before taking samples to eliminate any contamination. An 8 ounce plastic, disposable baby bottle is the best kind of container to use. It is commonly recommended to rinse the container several times with the water to be tested before collecting the final sample. Always clearly identify each container with specific sample identification (well site). When mailing samples, place the bottles in a box or pack them with a soft packing material (newspaper or styrofoam) to prevent crushing.

COLLECTING WATER SAMPLES

Wells: For well water, allow the pump to operate for at least 20 minutes, or longer, before taking the sample to be sure the water is representative of what is being applied. Take the water sample at the pump so that residues from the lines do not contaminate the sample. If two or more wells supply an irrigation system, one sample may be taken from the system after pumping (flushing) for at least one hour. However, if the water test indicates a problem, all wells supplying the system will need to be tested individually to determine the source of the problem. Sometimes one poor quality well can dramatically reduce the quality of the mixture.

Surface Water: Testing also should be done on irrigation water obtained from ponds, reservoirs, streams or other surface water sources. Samples can be obtained by collecting water from a faucet near the pumping station after operation for 20 minutes or longer. For proposed irrigation water sources where no pump is present, samples can be obtained by attaching a clean bottle to a pole or extension and collecting and mixing several samples into a "composite" which is sent to the laboratory. Package and mail all samples to the laboratory as soon as possible to prevent chemical changes in the water due to storage. Keep good records of the date and location of each sample. This can best be done by keeping a copy of the Laboratory Information Sheet which must be submitted with each sample. In most cases, a Routine Irrigation Water Analysis is the most appropriate test to request for irrigation water.

Table 5 Irrigation Water Quality Rating for Crop Production[1/]

Potential Irrigation Water Quality Problem	Describing Parameter	--Degree of Restriction on Use --		
		None	**Slight to Moderate**	**Severe**
Salinity (Affects crop water availability)				
	ECi [2/], mmho/cm	<0.7	0.75 – 2	>2.0
	or TDS [3/], mg/L	<450	450 – 2,000	>2,000
Infiltration (Affects water infiltration rate evaluated by using ECi and SAR together) [4/]	**SAR**		**ECi, mmho/cm**	
	0 – 3	>0.7	0.7 – 0.2	<0.2
	3 – 6	>1.2	1.2 – 0.3	<0.3
	6 – 12	>1.9	1.9 – 0.5	<0.3
	12 – 20	>2.9	2.9 – 1.3	<1.3
	20 – 40	>5.0	5.0 – 2.9	<2.9
Specific Ion Toxicity (Affects sensitive Crops)				
Sodium (Na) [5/]				
Micro-Tape/Drippers	SAR	<3	3 – 9	>9
Micro-Sprinkler/Spray	meq/L	<3	>3	
Chloride (Cl^-) [5/]				
Micro-Tape/Drippers	meq/L	<4	4 – 10	>10
Micro-Sprinkler/Spray	meq/L	<3	>3	
Boron [6/]	meq/L	<.7	0.7 – 3.0	>3.0
Miscellaneous Effects (Affects susceptible crops)				
Bicarbonate (HCO_3)				
(overhead sprinkler only)	meq/L	<1.5	1.5 – 8.5	>8.5

1/ Adapted from Ayers and Westcot (1985), FAO 29, revision 1.
2/ ECi means electrical conductivity of the irrigation water reported in mmho/cm at 77ºF (25 ºC).
3/ TDS means total dissolved solids reported in mg/L.
4/ SAR stands for Sodium Adsorption Ratio. At a given SAR, infiltration rate increases as water salinity increases.
5/ For surface irrigation—Most tree crops and woody plants are sensitive to sodium and chloride, so the values shown should be used. Because most annual crops are not sensitive, the salinity tolerance values in table 2-34 should be used. For chloride tolerance of selected fruit crops, see table 2-35 in NEH, Part 623, Chapter 2, Irrigation Water Requirements. With overhead sprinkler irrigation and low humidity (<30%), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see table 2-36 in NEH, part 623, chapter 2
6/ For Boron tolerances see tables 2-37 and 2-38 in NEH, Part 623, Chapter 2, Irrigation Water Requirements.

Table 6 Recommended Maximum Concentrations of Trace Elements in Irrigation Water 1/ 2/

Element	**Recommended Maximum Concentration (mg/l)** 3/	**Remarks**
Al (aluminum)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn (manganese)	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni (nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd (lead)	5.0	Can inhibit plant cell growth at very high concentrations
Se (selenium)	0.02	Toxic to plants at concentrations as low as .025mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH>6.0 and in fine textured or organic soils.

1/ F.A.0., Water Quality for Agriculture, Ayers and Wescott (1985)
2/ Adapted from National Academy of Sciences (1972) and Pratt (1972)
3/ The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 m^3 per hectare per year (39 inches)). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3 per hectare per year. The values given are for water used on continuous basis at one site.

REFERENCE

Adapted from Arizona USDA NRCS; eFOTG, Section 4
http://efotg.sc.egov.usda.gov/treemenuFS.aspx