SDI WATER QUALITY ASSESSMENT GUIDELINES

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INTRODUCTION

Water quality can have a significant effect on Subsurface Drip Irrigation (SDI) system performance and longevity. In some instances, poor water quality, such as high salinity, could cause soil quality and crop growth problems. However, with proper treatment and management, water with high mineral loading, water with nutrient enrichment or water with high salinity can be used successfully in SDI systems. However, no system should be designed and installed without first assessing the quality of the proposed irrigation water supply.

SAMPLING REQUIREMENTS

Water samples should be collected in clean triple rinsed plastic bottles. Well water samples should be collected after the well has been operating for at least 15 minutes. Surface water samples should be collected below the water surface. If the quality varies throughout the pumping season, chose the worst case sample, or sample multiple times. Generally about a half gallon of water is needed to perform the required chemical analysis. The samples need to be analyzed within 3 hours. If this is not practical, the samples can be frozen or held below 40°F. *It is advisable to check with the lab for specific collection and handling instructions for the sample.* Be certain to let them know the type of tests of interest. These tests are discussed below.

points of the two materials into the water stream should be at least 2 to 3 feet apart. *Acid and chlorine source bleach should never be combined in the same container, because dangerous toxic chlorine gas is released.* Pump lubrication oil may cause plugging of the screen. Selecting lubrication material may help. There are some materials that may break the greasy substance produced from lubricants by soap action.

Concluding Statements

When using SDI systems, it is important to prevent clogging problems to ensure that the system will last for many years. To be economical the SDI system require to perform well for at least 15 years, which is very much possible. The best prevention plan includes an effective filtration and water treatment strategy. Depending on the water source and its quality, various combinations of sand separation, screen filtration, sand media or disk filtration, chlorination, and acid injection may be required. Filtration equipment may be the single item of greatest cost when installing the SDI system. One must resist the temptation to "cut corners." Good filtration and system maintenance will pay for itself by avoiding labor, or extra effort that may be required to fix a damaged system that was not adequately maintained. Despite all efforts on filtration, some materials will not be removed and will find their way into the drip tape. To prevent the accumulation of those materials in the drip tape and the resultant emitter clogging, the drip tapes should be flushed occasionally. A useful way to provide flushing is to connect all the distal ends of the drip tape laterals within a zone to a common sub main or flush header. This allows the flushing to be accomplished from one point, and helps in keeping the system free from accumulated sediments while providing water below the clogging point of any plugged drip tape. If a break occurs, positive water pressure on both sides will limit sediment intrusion. Flow meters and pressure gauges should be checked periodically to assure that the system is operating correctly. If measured flow rates and pressure distributions indicate problems in the system, some reconditioning may be possible with chemical injection (including chlorine shock treatments), flushing, and other steps. Profit margins for crops typically grown in the Great Plains are not as high as the profit margins for fruits and vegetables traditionally grown with SDI systems. To make SDI systems in the Great Plains economically viable— they must have a long life. Prevention of clogging is therefore critical to the successful and economical use of SDI in the Great Plains.

Reference

Alam, M. et al. 2002. Filtration and Maintenance Considerations for Subsurface Drip Irrigation (SDI) Systems. MF-2361 (Revised), Kansas State University.

Visit K-State web page on SDI at: http://www.oznet.ksu.edu/sdi
Also at: http://www.oznet.ksu.edu/library/ageng2/

WATER QUALITY ANALYSIS RECOMMENDATIONS

Prevention of clogging is the key to SDI system longevity and prevention requires understanding of the potential problems associated with a particular water source. Information on water quality should be obtained and made available to the designer and irrigation manager in the early stages of the planning process so that suitable system components, especially the filtration system, and appropriate management and maintenance plans can be selected. Recommended water quality tests include:

1. **Electrical Conductivity (EC)**, measured in ds/m or mmho/cm. A measure of total salinity or total dissolved solids;
2. **pH**, a measure of acidity - where 1 is very acid, 14 is very alkali, and 7 is neutral;
3. **Cations** - measured in meq/L (milliequivalent/liter), includes:
   Calcium (Ca),
   Magnesium (Mg), and
   Sodium (Na);
4. **Anions** - measured in meq/L, includes:
   Chloride (Cl),
   Sulfate (SO4),
   Carbonate (CO3), and
   Bicarbonate (HCO3);
5. **Sodium Absorption Ratio (SAR)** - a measure of the potential for sodium in the water to develop sodium sodicity, deterioration in soil permeability and toxicity to crops. SAR is sometimes reported as Adjusted (Adj) SAR. The Adj. SAR value better accounts for the effect on the HCO3 concentration and salinity in the water and the subsequent potential damage by sodium to the soil.
6. **Nitrate nitrogen (NO3 - N)** - measured in mg/L (milligram/liter);
7. **Iron (Fe)**,
   Manganese (Mn), and
   Hydrogen Sulfide (H2S) - measured in mg/L;
8. **Total suspended solids (TSS)** - a measure of particles in suspension - in mg/L;
9. **Bacterial population** - a measure or count of bacterial presence in # / ml, (number per milliliter);
10. **Boron*** - measured in mg/L;
11. **Presence of oil****

* The boron test would be for crop toxicity concern.
** Oil in water would be concern for excessive filter clogging. It may not be a test option at some labs and could be considered an optional analysis.

Tests 1 through 7 are likely to be test results provided in a standard irrigation water quality test package. Tests 8 through 11 are generally offered by water labs as individual tests. The test for presence of oil may be a test to consider in oil producing areas of the state or if the well to be used for SDI has experienced surging which may have introduced oil into the pumped water. The fee schedule for tests1 through 11 will vary from lab to lab. The total cost for all recommended tests may be a few hundred dollars. This is still minor investment in comparison to the value offered by the test in helping to determine proper design and operation of the SDI system.

Water testing can be done by a number of laboratories in the state; be sure to use a certified lab. *Remember to always check with the lab in advance of collecting any sample for specific collection procedure, test kits or handling procedures needed to assure quality.* Table 1 summarizes the water quality guidelines for clogging potential. These are guidelines to help interpret water quality test results.

Most surface and groundwater supplies in the region will be fairly hard, that is they will have a large mineral content. In addition, many wells, especially older wells, may produce sand when pumping. These two clogging hazards are classified as chemical and physical hazards, respectively. A third clogging hazard is biological which could be slimes produced by growth of bacteria or algae.

Bacteria do not normally live in groundwater until a well allows the introduction of bacteria, an air exchange, and, in some cases, a source of nutrients. Bacteria can live on iron, manganese or sulfur. Their growth process produces a slime that can build up on the well screens and actually cause well yield declines. A bacteria contaminated well will introduce the bacteria into the SDI system which can result in clogging of the filtration system and dripline emitter. Chlorination of an irrigation well to kill bacteria, should be a routine practice (probably at least annually). Treat the well with a shock treatment of about 500 ppm. Details for shock chlorination of wells are discussed by Powell and Rogers, 1998 or contact your local well driller. A simple Excel template to calculate the chlorine rate for chlorination of deep wells is at
http://www.oznet.ksu.edu/sdi/Software/SDISoftware.htm

A well that has been shock chlorinated should be pumped to waste until the water clears. This water should never be sent through the SDI system since there will be large amounts of dislodged chemical and biological material from the well casing and screen.

Table 1. Water quality guidelines for microirrigation systems. Adapted from Hanson et. al., 1994 and Hassan, 1998.

Constituent	Level of Concern		
Clogging Potential	**Low**	**Moderate**	**High**
pH	< 7.0	7 - 8	> 8.0
Iron (Fe) mg/L	< 0.2	0.2 - 1.5	> 1.5
Manganese (Mn) mg/L	< 0.1	0.1 - 1.5	> 1.5
Hydrogen Sulfide (H_2S) mg/L	< 0.2	0.2 - 2.0	> 2.0
Total Dissolved Solids (TDS) mg/l	< 500	500 - 2000	> 2000
Total Suspended Solids (TSS) mg/L	< 50	50 - 100	> 100
Bacteria Count (# / mL)	< 10,000	10,000 - 50,000	> 50,000
Crop Effects	**Low**	**Moderate**	**High**
EC - mmho/cm	< 0.75	0.75 - 3.0	> 3.0
NO_3 - mg/L	< 5	5 - 30	> 30
Specific Ion Toxicity	**Low**	**Moderate**	**High**
Boron - mg/L	< 0.7	0.7 - 3.0	> 3.0
Chloride - meq/L	< 4	4 - 10	> 10.0
Chloride - mg/L	< 142	142 - 355	> 355
Sodium (Adj SAR)	< 3.0	3 - 9	> 9

Chlorination of the SDI system is also a practice that should be a routine maintenance procedure, since chlorine will oxidize biological material. Bacterial growth in driplines can be additionally troublesome due to small clay particles in the water that are smaller than the required level of filtration. The sticky slime growth may cause these small particles to stick together with the resultant effect of clogging emitters.

Chlorine can be injected to kill bacteria either continuously with a low dosage base (0.5-1.5 ppm) or periodically at a high dose of 5 to 20 ppm. Periodic dosage is most common in Kansas systems. The dosage level should be sufficient that a concentration of 0.5 to 1 ppm of free chlorine should be measured at the end of the system. Chlorine is more effective in acid waters. High pH or alkaline waters should be acidified to a pH of 6.5 for effective chlorine treatment. Acid treatment can also an effective treatment for bacteria growth.

The general formula for calculating the amount of chlorine to inject in liquid form (sodium hypochlorite, NaOC) is:

$$IR = Q \times C \times 0.006/S$$

where
IR = Chlorine injection rate (gal/hour)
Q = Irrigation system flow rate (gal/min)
C = Desired chlorine concentration (ppm)
S = Strength of NaOC solution used (percent)

Example: *A grower wishes to use household bleach (NaOC at 5.25 percent active chlorine) to achieve a 15 ppm chlorine level at the injection point. The flow rate of the irrigation systems is 700 gpm. At what rate should the NaOC be injected?*

IR = 700 gpm x 15 ppm x 0.006 / 5.25
= 12 gallon per hour

At an irrigation flow rate of 700 gpm, the grower is pumping (700 x 60) 42000 gph (i.e. 700 x 60). The goal is to inject 12 gallons of bleach into 42000 gallons of water each hour that injection occurs.

If the injector is set for a 500:1 ratio, it will inject 42000/500 or 84 gallons per hour. Then, 12 gallons of bleach should be added to 72 gallons of water to make the 84 gallons of stock solution. Note: be careful to use the same time units (hours) when calculating the injection rate.

Common household bleach is generally a 5.25 to 7.5 percent solution. Stronger concentrations of chlorine solutions are available from irrigation dealers and industrial suppliers.

The injected chlorine must travel through the entire system during the injection period. The propagation time should be calculated or obtained from the installer. Alternatively, water from the flushline can be tested to see if a free chlorine residual is detected. This would indicate a sufficient injection time has elapsed.

CHEMICAL PRECIPITATION

Chemical precipitation hazard guidelines, as shown in Table 1, give some indication of potential clogging hazard. SDI systems have an advantage over surface drip systems in that the driplines are below ground and buffered from sunlight and temperature that could help drive both biological and chemical activity. Water pH and temperature also plays a major role in many reactions.

In addition to the discussion to follow, several references also noted groundwater test interpretations and are summarized in Table 2.

Table 2. Notes on Chemical Clogging Hazards

Bicarbonate concentrations exceeding about 2 meg/L and pH exceeding about 7.5 can cause calcium carbonate precipitation.
Calcium concentrations exceeding 2 to 3 meg/L can cause precipitates to form during injection of some phosphate fertilizers. Special procedures are necessary for the injection of phosphate fertilizers and injection should be only attempted by experienced personnel using care.
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.
Irrigation water containing more than 0.1 ppm sulfides may encourage growth of sulfur bacteria within the irrigation system. Regular chlorination may be needed.
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.

CALCIUM CARBONATE

Calcium carbonate, commonly known as lime, can be a problem with high pH (>7.5) and high bicarbonate levels (> 2meg/L). The symptoms of calcium precipitation is a white film or plating on the dripline or around the emitters or white precipitants in the flush water of the driplines.

The usual treatment for calcium precipitation is to acidify the water by lowering the pH to 7.0 or lower with continuous injection. Calcium becomes more soluble at low pH. When using a periodic injection treatment, pH may have to be lowered to 4.0 or less and allowed to sit in the system for up to 60 minutes.

Temperature, pH and the calcium concentration all affect calcium solubility, so conditions will vary throughout the system. Litmus paper, colormetric kits, or a portable pH meter can be used to measure the pH at the lower end of the system to determine if free chlorine exists.

Sulfuric acid or hydrochloric acid can be used to reduce pH. Muriatic acid (20% hydrochloric acid) may be the most commonly available acid from hardware or farm supply stores. Urea sulfuric acid, an acid with nitrogen fertilizer value, can also be used. This product is safer to use and is marketed as N-pHuric *. Check with your irrigation dealer or your fertilizer dealer about its availability in your region. **Caution: Use extreme care in handling acids and always add acid to water.** Be certain to flush and clean the injection system after an acid treatment as the acid may be corrosive to internal parts. Remember also, treatments need to be done before total blockage of emitters occur. Remediation, after total blockage, is difficult or impossible since the acid will not come into contact with the precipitants in passages closed to water movement.

IRON AND MANGANESE

Iron and manganese precipitation can become a problem with concentrations as low as 0.1 ppm. Most groundwater contains some iron and manganese but in a soluble state but when exposed to air, they oxidize and precipitate as a solid. Irrigators with center pivots, especially center pivots using alluvial groundwater supplies, often see the structures turn red in very short usage times. These compounds can also be used as an energy source by bacteria. They form the filamentous slime, discussed previously, that can clog filters and emitters and act as a glue to adhere other contaminants together.

Symptoms of iron precipitation would be reddish stain and rust particles in the flush water and reddish deposits in the orifices. Manganese would be similar but darker color or black. Bacterial slimes would be of similar color as precipitants but appear as filamentous sludge in the flush water or collected on the screens.

AERATION AND SETTLING

One effective option for removal of high concentrations of iron and manganese for high flow rate systems is the use aeration and settling basins, especially for manganese. The oxidation rate of manganese is much slower than for iron, making manganese problematic for removal with some of the other treatment methods.

Aeration of the source water occurs by spraying water into the air or running it over a series of baffles to enhance the mixing of oxygen into the water. There must be sufficient aeration and reaction time; the soluble forms of manganese and iron will oxidize and precipitate. The disadvantage of this treatment is the need for a second pump. Total head requirements are not changed when using two pumps, so energy costs are not a major factor. Additionally, a settling basin requires a site, will entail construction costs, and have long term maintenance requirements. Algae and bacteria control in the basin by chlorination may be required.

CHLORINATION AND FILTRATION

Injection of chlorine into water will cause the dissolved iron to precipitate, so it can then be filtered out. The reaction occurs quickly but injections need to be located well upstream of the filter. This treatment method may be best suited for systems with sand media filters. Chlorine is injected at a rate of 1 ppm for each 0.7 ppm of iron. Additional chlorine may be required if other contaminates, such as iron bacteria, are also present. This treatment requires continuous injection of chlorine. Successful treatment also requires complete mixing of the chorine in the water.

This treatment method is not suited to manganese removal because of its slower oxidation rate. If manganese and free chlorine remain in the line after filtration, precipitation may then occur which could clog emitters.

pH CONTROL

Iron is more soluble at lower ph, therefore acid can be used on a continuous or periodic treatment basis as described for calcium carbonate. In this case, the pH should be lowered to 2.0 or less for 30 to 60 minutes for a periodic or cleaning treatment. After a periodic treatment, the system must be flushed.

IRON AND MANGANESE SULFIDES

Dissolved iron and manganese, in the presence of sulfides, can form a black sand-like insoluble precipitant. The recommended treatment for this combination of compounds would be continuous acid injection that lowers pH to between 5 and 7.

Sulfur slime can also be produced by bacteria that can oxidize hydrogen sulfide and produce elemental sulfur. The systems of this condition are white cottony masses of slime which either clog emitters directly or again act as glue to collect small silt and clay particles that clump together and then clog emitters.

TREATMENT SUMMARY

The symptoms and treatments for the various clogging hazards are summarized in Table 3.

Table 3. Water treatments to prevent clogging in microirrigation systems. Adapted from Hanson et. al, 1994

Problem	Treatment Options
Carbonate precipitation (white precipitate) *Hazard level:* HCO_3 greater than 2.0 meq/l pH greater than 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 precipitation (reddish precipitate) *Hazard level:* Iron concentrations greater than 0.1 ppm	1. Aeration and settling to oxidize iron. (Best treatment for high concentrations-10 ppm or 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 precipitation (black precipitate) *Hazard level:* Manganese 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) *Hazard level:* 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 daily.
Sulfur bacteria (white cottony slime) *Hazard level:* 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 for 30 to 60 minutes daily.
Bacterial slime, Algae	1. Inject chlorine at a rate of 0.5 to 1 ppm continuously or 20 ppm for 20 minutes at the end of each irrigation cycle.
Iron sulfide (black sand-like material) *Hazard level:* Iron and sulfide concentrations greater than 0.1 ppm	1. Dissolve iron by injecting acid continuously to lower pH to between 5 and 7.

SUMMARY

Subsurface drip irrigation offers a number of agronomic production and water conservation advantages but requires proper design, operation, and maintenance to be an efficient, effective and long-lived irrigation system. One management change from the current irrigation systems is the need to understand the SDI system sensitivity to clogging by physical, biological or chemical agents.

Before designing or installing an SDI system, be certain a comprehensive water quality test is conducted on the source water supply. Once this assessment is complete, the manager can then be made aware of any potential problems that might be caused by the water supply. The old adage "an ounce of prevention is worth a pound of cure" is very appropriate for SDI systems as early recognition of developing problems can head off many problems if appropriate action is taken. Developing problems can be easily handled as compared to remediation of a clogged system. While this may seem daunting at first, as with most new technology, most managers will quickly become familiar with the system and its operational needs.

REFERENCES AND RECOMMENDED READINGS

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KSU RESEARCH FOR CORN PRODUCTION USING SDI: 14 YEARS OF PROGRESS

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BRIEF HISTORY

In the summer of 1988, K-State Research and Extension issued an in-house request for proposals for new directions in research activity. A proposal entitled Sustaining Irrigated Agriculture in Kansas with Drip Irrigation was submitted by irrigation engineers Freddie Lamm, Harry Manges and Dan Rogers and agricultural economist Mark Nelson. This project led by principal investigator Freddie Lamm, Northwest Research-Extension Center (NWREC), Colby, was funded for the total sum of $89,260. This project financed the initial development of the NWREC SDI system that was expressly designed for research. In March of 1989, the first driplines were installed on a 3 acre study site which has 23 separately controlled plots. This site has been in continuous use in SDI corn production since that time, being initially used for a 3-year study of SDI water requirements for corn. In addition, it is considered to be a benchmark area that is also being monitored annually for system performance to determine SDI longevity. In the summer of 1989, an additional 3 acres was developed to determine the optimum dripline spacing for corn production. A small dripline spacing study site was also developed at the Southwest Research-Extension Center (SWREC) at Garden City in the spring of 1989.

In the summer of 1989, further funding was obtained through a special grant from the US Department of Agriculture (USDA). This funding led to expansion of the NWREC SDI research site to a total of 13 acres and 121 different research plots. This same funding provided for the 10 acre SDI research site at Holcomb, Kansas administered by the SWREC. By June of 1990, K-State Research and Extension had established 25 acres of SDI research facilities and nearly 220 separately controlled plot areas.

Over the course of the past 14 years, additional significant funding has been obtained to conduct SDI research from the USDA, the Kansas Water Resources Research Institute, special funding from the Kansas legislature, the Kansas Corn