Basic Water Treatment: Theory & Practical Application

Micro irrigation systems are a wonderful invention for delivering water and fertilizer directly to plants with the least amount of water at a low cost. The biggest problem with micro irrigation systems is the “micro” part. Small emitters plug easier than larger emitters. The plugging of emitters is the biggest problem with “micro” irrigation systems. Emitter plugging can result many causes such as physical (grit), biological (bacteria and algae), or, as some claim, chemical (iron and calcium scale). Frequently, plugging is caused by a combination of more than one of these factors.

The rules for using water are the same for every industry that uses water. The practical applications of water treatment rules are the same for industrial cooling, fountains, agriculture, turf, and horticulture. There isn't any magic to the application and use of water. There are just some common sense rules to follow. There are several key factors for using water for irrigation: algae and bacteria, iron, and calcium. These factors are considered the most common problems encountered with irrigation systems.

ALGAE

Blockage caused by algae is the most common problem in irrigation systems. The reason why is that algae reproduces prolifically where there is moisture and warmth. The Ideal conditions for growing algae are the same conditions found in irrigation systems. And grow it does!

Algae (sing. alga) are a large and diverse group of simple organisms. They can be either unicellular or multicellular forms. Algae can use the sun to produce food through photosynthesis like plants, but they are "simple" because they lack the many distinct organs found in higher developed plants. Algae are eukaryotes (organisms whose cells are organized into complex structures enclosed within cell walls. Algae are distinguished from protozoa in that they can use photosynthesis to produce food. The process of photosynthesis produces oxygen as a by-product.

Algae reproduce asexually and the cycle of duplication is between 7 and 14 days depending on the strain and conditions. Because algae are asexual, their reproduction rates are not dependent on fertilizing eggs and their reproduction rate is continuous and exponential in numbers.

Think of a swimming pool as an example. Normal chlorine treatment is recommended at no less than every 7 days. Because on the 8^{th} or 9^{th} day, algae us usually visible. Preventive treatment is an attempt to keep the number of colonies low enough that they aren't visible. Algae in non-pathogenic to animals and plants, but it can make using the water difficult. Chlorine kills the algae, but it requires a filter is still required to remove dead cells from the pool water. Chlorine does not remove live or dead algae cells even when super chlorinated.

World-wide it is thought that there are over 15,000 separate species of algae which are: 5,000 species of red algae, 2,000 of brown algae and 8,000 of green algae.

You've probably heard a grower state “I have good water and I don't have any problems with algae”. This is a common belief and hopefully it will hold true for those growers. However, there is a nursery in Louisiana that use RO water (similar to distilled water) and the algae still grow prolifically in their irrigation system. The overhead sprayers plug within weeks of being replaced.

Another statement that is made is “let's take a water sample and see what's in the water". That's good to do occasionally, but there is no easy test for microorganisms that grow in these systems. The microorganisms are so small that it would take filtering several hundred gallons with very fine filtration to collect enough cells to run a culture. Almost all water will grow algae under the right conditions. Micro irrigation systems provide the optimal conditions for algae growth.

Treatments: No remedies have been effective for preventing the growth of microorganisms until recent innovations. Many treatments have been tried including chlorine (powder, liquid, & gas), chlorine dioxide, UV lights, ozone, mineral acids, quats (quaternary ammonium compounds), peroxide, and several others. None of these treatments has been effective to prevent or remove the microorganisms. The only treatment that has proven effective is a peracetic based product.

Chlorine only kills microorganisms, but it leaves the dead cells in the system which becomes food for other organisms. Chlorine has no residual effect. A continuous feeding of chlorine may allow organisms to become resistant to chlorine. Chlorine will then be less effective.

Being simple cell organisms, they don't have sophisticated defenses. One response they do have is reproduction. When algae colonies are attacked, they can immediately put an all out effort to reproduce. An algae bloom can occur. A bloom occurs when the reproduction rate grows dramatically and algae become visible. The colonies can become larger masses and are stringy.

Chlorine, at lower dosages of 1-15 ppm, will only kill the outside layer of a colony and has no ability to penetrate into masses. Chlorine added at a high enough dosage to remove colonies can be toxic to plants, corrosive to metals, and can even destroy plastic parts by removing the moisture (desiccating) the plastic. The plastic can then fracture which can cause the damage to emitters.

An example of how chlorine works is washing clothes. At a medium dosage (15 – 25 ppm) of chlorine, it will bleach out some organic stains (not blood). At a much higher dosage (super chlorination), it will destroy the fabric by burning holes in the clothing (and can do the same thing to plants). At lower dosages of 1-2 ppm of chlorine, it may kill a few organisms, but even at this dosage, slime can still form in the pipes of drinking water systems. In some municipal systems, non-pathogenic bacteria will grow in the system readily. Chlorine will not remove these organisms unless the system is super chlorinated.

Some “quats” (Quaternary Ammonium Compounds) are being used in an attempt to prevent blockage. An example of quats in common usage is Lysol. Quats work by attaching to the cells and bursting the cell walls, but a contact time of 10 minutes or longer is required. Dead cells are left behind which once again can be used as food for new colonies. Quats are very expensive and are rarely fed at the manufacturer's recommended rate of 25 to 50 ppm. Label directions clearly state to remove all organic matter before applying the quaternary compounds to the area.

Hydrogen peroxide is an effective cleaner, but requires a very high dosage. Peroxide isn't cost effective to use. It is effective at cleaning filters (particularly sand media). The high dilution rate makes using peroxide too expensive to use for preventing or removing organic deposits in micro irrigation systems on a large scale basis.

Another treatment method of cleaning irrigation lines is to use mineral acids (hydrochloric, nitric, n-furic, sulfuric acids). Mineral acid treatments are injected into the lines to remove either calcium or microorganisms. Mineral acids have no ability to kill microorganisms. They have no oxidizing or disinfectant properties, and have little effect. A very high dosage could physically destroy the cells, but that would take a huge amount of acid to fill the lines and just the fumes could kill plants. The mineral acids are very corrosion to most metals and could severely damage the plants. To remove calcium scale requires a pH of <2.5 which is deadly to plants and too expensive to use. A proposed dosage is 1-2 tons per acre. Reports indicate that it may be effective for a few days, but then the blockage returns. No study of their effectiveness has been reported.

A stabilized peracetic complex has been formulated that destroys organics. The pH is not affected. It leaves no residue, and, breaks down to water and carbon dioxide. Its low dosage results in low cost to use. It removes organics in irrigation systems. It is the only product we know of that removes blockage in micro irrigation systems. For more information, see http://www.lineblaster.com/.

BACTERIA

Bacteria work very similar to algae, but do not use photosynthesis for the production of food. They have more sophisticated structures. Sulfur slimes and sulfate reducing bacteria are probably the two types of bacteria that will cause most of the bacterial problems with micro irrigation systems. Both readily form colonies and can be pumped out of wells in great volumes. At times, the residue from the bacterial colonies looks like tissue paper when collected. They produce hydrogen sulfide gas (rotten egg smell) as a by-product and this can be used to determine their presence. Sulfur slimes and sulfate reducing bacteria are more difficult to remove than algae due to the tighter formation of colonies and the carbohydrate sheath of “chitin” that protect the cells. Chlorine has no effect on these bacteria at all. As a general rule, chlorine won’t even kill the sulfur slimes and sulfate reducing bacteria due to the carbohydrate sheath surrounding these organisms. Chlorine does not penetrate the sheath and can’t kill the bacteria. Peracetic acid compounds mentioned above has proven effective in penetrating the carbohydrate sheath to remove colonies.

IRON

Iron probably accounts for the second most problems in micro irrigation systems. Most water that contains iron is taken from wells. Iron is an element which means it can’t be eliminated with chemical treatment. Iron could be filtered or removed by RO, distillation, or other process, but the cost of eliminating iron is staggering. The volume of water is much too great to be treated by mechanical processes.

Iron is found in two states: ferrous (black) and ferric (red). The ferrous iron molecule is more soluble and is not visible when dissolved in water. The ferric molecule is formed when ferrous iron is combined with oxygen and converts the ferrous iron to ferric iron. This is called oxidation which is basically:

Ferrous Iron + Oxygen = Rust (Ferric Iron)

It is the ferric iron that causes the reddish-orange rust staining. The formula is listed below.

$$2Fe^{++} + O_2 = Fe_2O_2$$

Ferrous Iron + Oxygen = Ferric Iron

When this reaction occurs, the iron in the ferrous state converts to iron in the ferric state. It is still an iron compound and always will contain iron. The iron just changes the compound with the addition of oxygen. Once this reaction occurs, it cannot be reversed and there isn't any process outside of expensive mechanical processes to remove the ferric iron. The iron needs to be treated before it converts to the ferric iron state.

The ferrous iron is soluble and is dissolved in the water. Acid can be added to the water to keep the iron from coming out of solution, but the pH of the water after adding acid is too low for applying to plants. The ferric iron is a heavier compound and it is more likely to fall out of solution which can result in iron deposits.

One of the properties of this reaction (conversion) is that it takes from 4 to 12 hours to complete. It means the ferric iron is not visible for a few hours. To have a visible confirmation of iron in the water, collect a glass jar of water. When first collected, the water will appear clear and free of residue. The bottom of the container will be free of any iron particles. After a period of 4 to 12 hours, the iron will drop to the bottom of the jar. Iron normally will have turned to a dull brick-orange color and appear to be very light in texture. The iron particles are wispy-like when lightly swirled.

Although iron really does not cause plugging, there are several different ways that have been used for treating iron. One is to inject chlorine into water with iron to control the "iron deposits". The formula that has been proposed is "to continuously inject chlorine at the rate of 0.6 ppm of chlorine/ppm ferrous iron, and then adjust chlorine levels to a 1 ppm residual at the end of the line." This will accelerate the oxidation process. The idea is to not cause plugging. If the iron is induced to fall out of solution, there may be enough iron to actually cause plugging. Under normal operating conditions, iron does not cause plugging. Chemically inducing iron to precipitate may cause plugging.

Another treatment for iron that is being used is to dig a pond (or use a large tank). Pump the well water into the pond (tank) allow the iron to naturally oxidize and fall out of solution. The iron will naturally settle to the bottom of the pond or tank. The suction point of the irrigation pump must be raised off the bottom of the tank. This avoids pumping the iron through the system. There have been instances in which the iron builds up to such a level that the iron in the water being drawn from the pond is higher in iron content that the water coming directly out of the well. At that point, it may be a good idea to dig a new pond and start over. A factor to consider is the cost. This process requires two pumps (one pumping into the pond and the other out of the pond), the cost of digging the pond and the cost of the land.

Polyphosphates have been injected into irrigation water to bond with the iron to prevent the iron from converting to the ferric state. The iron bonds tighter with the polyphosphate and will not let the oxygen bond with the iron. This prevents the oxidation from taking place and is highly effective. However, this is usually reserved for horticulture and residential irrigation systems. As noted above, in agriculture the iron isn't a real threat and iron on the ground does not hurt the product. In horticulture, no one wants to by a rust stained plant. In residential applications, the stains are unsightly and stain sidewalks, houses, cars, and plants. I've even seen red grass due to heavy rust stains.

When water containing iron is used in micro irrigation systems, the iron should have enough time to exit the system before oxidation occurs. The iron will convert to the ferric compound and precipitate on the ground. The amount of water left in the drip tape will leave a light dusting of iron residue, but will never be enough to cause blockage. Even In some of the worst situations, water with an iron content of 10 ppm or higher, plugging from iron doesn’t occur. Consider a worst case scenario and how little iron is involved.

Example of Iron Distribution in Drip Tape

10 ppm iron in irrigation water @ 400 gpm

There is only 0.02 grams of iron per foot of Drip Tape in 299.8 hours of irrigation

This amount of iron is insignificant and won’t cause plugging. Also this is considering that none of the iron passes out of the irrigation system.

IRON BACTERIA

The difference between iron bacteria and iron obviously is the bacteria. Iron-related or iron-precipitating bacteria (Crenothrix) are a diverse group of microorganisms widely distributed in nature. They are found in fresh and salt waters, in soils, and on desert rock surfaces. Iron bacteria do not normally cause diseases to humans or animals, but rather, they are a nuisance microorganism. These bacteria do not need light or air to proliferate or multiply. They flourish and they obtain energy by the oxidation of dissolved iron in the water from the ferrous to the ferric state. The ferric form is precipitated as ferric hydroxide ($Fe(OH)_3$

Usually surrounded by a tubular "mucilaginous" sheath that hardens and becomes impregnated with ferric hydroxide, iron bacteria can be difficult to control. Chlorination has been used for control in bulk waters for many years; however, there are inherent drawbacks in the use of these products. High chlorine demand due to organic matter and iron levels has shifted the emphasis for control to the use of non-oxidizing biocides, such as quaternary ammonium compounds, as well as organo-sulfur compounds. Both chlorine and quats are only temporary and the problem comes back in a matter of days.

Iron bacteria thrive on iron and use it as a food source. It occurs in pockets that are localized. Iron bacteria can be found in one place and 10 miles away, the water is free of iron and iron bacteria. These microorganisms combine dissolved iron or manganese with oxygen and use it to form rust-colored deposits. In the process, the bacteria produce a brown slime that builds up on well screens, pipes, and micro irrigation systems.

There are certain indications that your well may have an iron bacteria problem. These are:

Red, yellow, or orange color to the water

Slime on the inner walls of irrigation system

A smell that may resemble fuel oil, cucumber, or sewage

For several reasons, routine chemical disinfectants that effectively wipe out other bacteria are only modestly successful against iron bacteria. Iron bacteria build up in thick layers forming a slime that keeps disinfectants from penetrating beyond the surface cells. In addition, miner iron dissolved in water can absorb much of the disinfectants before they reach the bacterial cells. Also, because chemical reactions are slowed at the cool temperatures common in wells, bacterial cells need a long exposure to the chemical for treatment to be effective. Even if chlorine kills all the bacterial cells in the water, those in the groundwater can be drawn in by pumping or drift back into the well.

There are both chemical and mechanical methods for treating iron bacteria problems. The mechanical processes for iron and iron bacteria are too expensive due to the volume of water required. It is possible and has been used on a small basis, but it has very little acceptance due to the cost. Most current treatments consist of dumping chlorine or other chemicals into the well and “hope that works for a while”. Chlorine tablets have been in use since they are slower to dissolve and may give a longer contact time. Since bacteria tend to build up again a few day or weeks after treatment, well owners should be aware that this only controls rather than completely "cures" the problem. While this may be a common practice among well drillers, the legality may be under scrutiny by the environmental agencies.

The most effective product is the peracetic acid that penetrates and removes organic blockages. It can be used continuously or intermittently depending on the operation and the amount of time irrigating.

CALCIUM

Calcium has been identified as a culprit in plugging. Calcium does not precipitate (fall out of solution) in micro irrigation systems. Micro irrigation systems operate as once-thru systems at ambient temperature. If you collect a sample of water and allowed it to sit overnight, there won’t be any residue from the calcium in the bottom of the container. This is an example of the calcium remaining soluble. The calcium does not precipitate in the container. If it doesn’t precipitate overnight, the calcium will completely flow through the system and remain soluble during the irrigation cycle. Perhaps there may be little white specs of calcium are visible. After 20 years of research, we have learned that the real culprit is the microorganisms (algae, bacteria, etc.). They form layers and begin to act like a filter. The calcium deposit forms when the water on the surface of the colonies evaporates. What is seen in micro irrigation systems is the white crusty calcium. Underneath the calcium is a usually a colony of algae or other microorganisms. When calcium is observed, the water sits on the layers of algae and when the water evaporates, the calcium is visible. If you remove the organics, the calcium will pass through the system. In 34 years of water treatment experience, no plugging has been discovered to be caused by calcium. If the calcium were to form deposits, using micro irrigation systems in Florida would be almost impossible due to the extremely high calcium levels of Florida water.

PHYSICAL BLOCKAGE

Flushing irrigation systems is another method used to control algae. Flushing will remove the loose colonies that collect at the end of the rows, but will not remove the colonies that adhere to the micro irrigation systems. Automatic flush valves do not allow many of the colonies to flow out of the lines. The colonies are heavy and will settle to the bottom of the system without pressure to push them out of the lines. Flushing helps to an extent, but is labor intensive and expensive and does not remove many of the colonies.

Sand, clay, grit, insects, and other debris can cause blockage in micro irrigation systems. The blockage caused by physical debris is either a filter, well or insect control problem. These problems can be eliminated by proper operation of the system and careful checking of operations. Before the season starts, the system should be checked for problems. Filters should be inspected and cleaned. Sock filters can be used to look for problems that may arise from split casings, sand infiltration, or other problems. A sock filter should be installed to detect problems with physical matter that may be in the micro irrigation systems. Checking the sock filter weekly may prevent a disaster from occurring. Blockages caused by physical debris are almost impossible to remove. There are no methods that are effective in dissolving sand, clay, grit, or insect parts. A physical hand cleaning is about the only method of removing physical blockage. It usually is easier to replace the micro irrigation system.