CIR1039

UF UNIVERSITY of FLORIDA
IFAS Extension

Treating Irrigation Systems with Chlorine [1]

Kati W. Migliaccio, Brian Boman and Gary A. Clark[2]

Introduction

Irrigation systems can become partially or completely clogged from biological growths of bacteria or algae which are often present in surface water and ground water. Bacteria and algae use chemical elements such as nitrogen, phosphorus, sulfur, or iron as nutrient sources to grow and develop (Figures 1 and 2) (Pitts et al., 2003).

Thus, irrigation systems that also receive nutrients (such as natural background concentrations in the water or from fertigation) may experience greater rates of clogging.

While all irrigation systems should have some type of filtration system, this alone cannot effectively remove microorganisms. Microorganism growth can result in clogged pipes, fittings, and emission devices (sprinklers, drippers, spray jets, etc.), decreasing water application amounts and reducing application uniformity and efficiency. The results of these are generally reduced agriculture productivity. A chemical method for removing microbial growth is chlorination. Proper injection methods and amounts of the chlorine chemical must be used to provide an effective water treatment program without damaging the irrigation system or the agricultural crop.

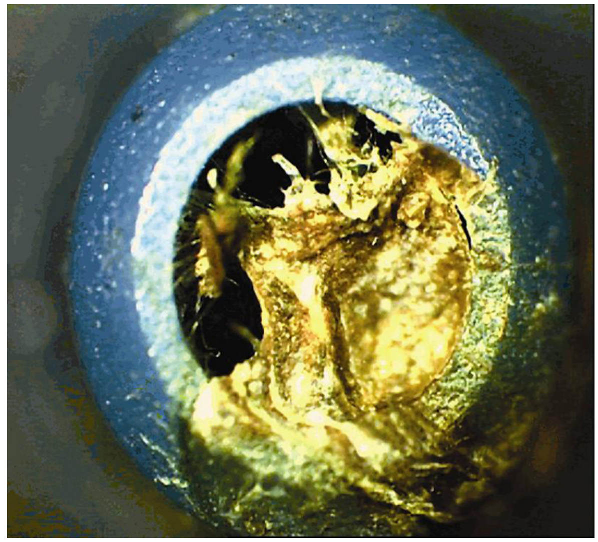

Figure 1. Irrigation emitter clogged with algal growth. Credits: Brian Boman UF/IFAS

This publication provides a guide for using chlorine to treat inhibiting microorganism buildup in irrigation systems.

1. This document is CIR1039, one of a series of the Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date July 1992. Reviewed February 2009. Revised May 2009. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.

2. Kati W. Migliaccio, assistant professor, Department of Agricultural and Biological Engineering, Tropical Research and Education Center (REC)--Homestead FL; Brian Boman, professor, Department of Agricultural and Biological Engineering, Indian River REC--Ft. Pierce FL; Gary A. Clark,associate professor, Department of Agricultural and Biological Engineering, KansasState University (formerly extension irrigation specialist, Gulf Coast REC--Bradenton FL); Originally written with Allen G. Smajstrla, professor, Department of Agricultural and Biological Engineering; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

Figure 2. Drip emitter covered with sulfur slime that was blocking irrigation flow. Credits: Brian Boman UF/IFAS

Chlorine

Chlorine, no matter the form, is a toxic and corrosive substance. Safety precautions should be observed at all times when handling chlorine. Appropriate protection equipment should be used (such as goggles, gloves, shoes, and clothing) to minimize the chance of direct contact with the chemical. A clean container should be used when chlorine is mixed with water. It is particularly important to ensure that no fertilizer residue is in the container as chlorine and fertilizer can create an exothermic reaction resulting in violent mixing of the contents. It is also important to remove any combustible materials from the area where chlorine will be stored or handled, and to keep fresh water available in case of accidental contact with the chlorine.

Chlorine may react with some metal and plastic components of irrigation systems. Therefore, always check with the manufacturer or supplier of system components to identify any potential problems before beginning a chlorine injection program. Chlorine should be injected before (upstream of) the system filter(s) so that any precipitates that form can be trapped in the filters. Filters should be cleaned on a regular basis to maintain their operational capabilities. The chlorine injection point should be far enough upstream of the filters to provide thorough mixing of the chlorine and irrigation water before it passes through the filter. This is required to ensure the removal of precipitates resulting from chlorine reactions. Elbows in the injection line may assist with the mixing process allowing for quicker mixing in less irrigation line length (Storlie, 2004).

Chlorine deteriorates over time and when exposed to heat and sunlight, therefore on-site storage should be kept at a minimum. Chlorine is sold in different forms: solid, liquid, or gas.

Solid Chlorine

Solid (or granular) chlorine forms, typically calcium hypochlorite, are commonly used to chlorinate swimming pools. Calcium hypochlorite is used to treat swimming pool water because the solid chlorine form is inexpensive, easy to store, and easy to use. It generally has 65 to 70 percent of available chlorine. Dissolving calcium hypochlorite in water will result in the formation of hypochlorous acid (HOCl) and hydroxyl ions (OH), a reaction that raises the pH of the water. Approximately 1.5 lb of calcium hypochlorite will treat 1,000,000 lb (120,000 gallons) of water with a 1 ppm concentration of Cl_2. It is important to note the rise in pH as chlorine is most effective under acidic conditions (Figure 3). Calcium hypochlorite injectors are available for small irrigation systems, are simple to use, and may be an alternative for low flow rate systems.

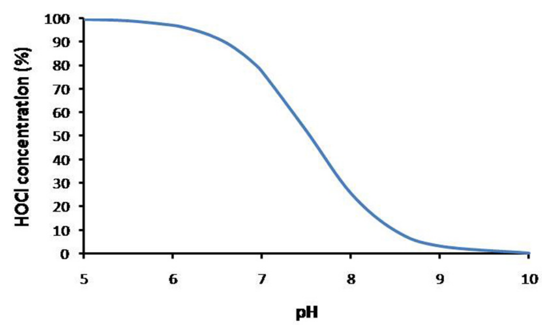

Figure 3. HOCl concentration at different pH for 25 C (77 F).

One drawback to using calcium hypochlorite to clean a clogged irrigation system is that the calcium may react with other elements in irrigation water to form precipitates which could clog micro-irrigation emitters and thus defeat the purpose for chlorination. Thus, solid chorine is not recommended. An alternative to solid chlorine is liquid chlorine. Liquid chlorine (sodium hypochlorite) should be used in irrigation systems, especially when the irrigation water source is high in minerals (such as the Floridian aquifer).

Liquid Chlorine

Liquid chlorine (or sodium hypochlorite) is most commonly used as laundry bleach. Mixing liquid sodium hypochlorite in water results in the formation of hypochlorous acid (HOCl) and hydroxyl ions (OH), a reaction that raises the pH of the water. It is important to note the rise in pH as chlorine is most effective under acidic conditions (Figure 3). Unlike the calcium added in the solid chlorine form, the sodium added in this liquid form does not contribute to clogging problems. The portion of active chlorine in sodium hypochlorite is generally 10% to 15%.

Gas Chlorine

The gas form of chlorine is commonly used in municipal water treatment systems. As chlorine gas reacts with water, hypochlorous acid (HOCl), hydrogen (H+), and chloride (Cl) are formed. This reaction lowers the pH of the water. The change in pH depends on how much chlorine gas is injected and on the buffering capacity of the water. Chlorine gas is 100% available active chlorine. Only 1 pound (lb) of chlorine gas (Cl_2) is required to provide a 1 ppm concentration of Cl_2 to 1,000,000 lb (120,000 gallons) of water. Similarly, an injection of 1 lb of chlorine gas per hour will provide a 1 ppm concentration of Cl_2 to a water supply with a flow rate of about 2,000 gallons per minute (gpm).

Extra precautions should be taken when using chlorine gas because it is a respiratory irritant which affects the mucous membranes. It can be detected as an odor at a concentration of 3.5 ppm and can be fatal after a few breaths at 1,000 ppm. Thus, maximum air concentrations should not exceed 1 ppm for prolonged exposure. Chlorine gas should only be used in well-ventilated areas so that any leaking gas cannot concentrate. The potential hazards associated with chlorine gas limit its application to experienced or licensed users and require the facility to abide by governmental reporting requirements.

To ensure safety, manufacturers have developed chlorine gas injectors for irrigation systems that work on a vacuum principle. A venturi injector is used to create a vacuum which actuates the injector. This design prevents chlorine gas from being injected unless the irrigation system is operating so that the gas is immediately dissolved in the irrigation water. For safety, only vacuum injectors should be used with chlorine gas.

pH

Hypochlorous acid (HOCl) is the effective agent in chlorination disinfection that controls bacterial growths. The amount of HOCl that will be present in solution, and thus active, will be larger at lower pH levels (more acidic conditions) (Figure 3).

If the irrigation water pH is high (as is often the case when pumping from the Floridian aquifer), the effectiveness of chlorine may be enhanced by injecting an acid to reduce the pH of the water before injecting chlorine (Nakayama, et al., 2007). In addition to increasing the effectiveness of chlorine, acid injection can also prevent the precipitation of minerals which may plug micro-irrigation systems. Chlorination is most effective when pH is at or below 7.2 (Boman, 2002). Note that it is very important to store chlorine and acid sources separately.

Chlorine Rates

Most microorganisms will be inactivated and controlled at free residual chlorine concentrations of 1 ppm. However, higher concentrations must be injected due to the inherent chlorine demand of different water sources. As a start, use 2 ppm of chlorine for each ppm of hydrogen sulfide, plus 0.6 ppm of chlorine for each ppm of ferrous iron. A chemical water test can be used to determine the levels of hydrogen sulfide or ferrous iron present in solution. Test kits are available from a variety of online sources and are easy to use (For more information on obtaining a test kit or determining chemical composition of irrigation water, contact your local extension agent or specialist). Water from surface sources such as lakes, ponds, or canals should be treated with approximately 5 to 10 ppm of chlorine. Higher levels may be needed for water with high amounts of microbial activity such as may occur during the warmer months of the year.

The chlorine injection rate should be checked by testing the treated water at the most distant part of the irrigation system using a test kit designed to measure "free" residual chlorine. Residual concentrations of 1 to 2 ppm at this location indicate that active chlorine still exists after the water and system parts have been appropriately treated.

Test for active chlorine using a diethyl-p-phenylene diamine (DPD) color indicating test kit that measures "free" residual chlorine. Do not use a test kit that only measures total chlorine. While levels of total chlorine may appear to be adequate, the active "free" residual form may not be adequate. Therefore, ask for a DPD test kit from either a swimming pool or irrigation supply company.

Chlorine Injection

After determining the desired chlorine concentration (or rate), the proper amount to be injected must be determined. The amount of chlorine to apply per gallon of irrigation water will depend on the desired concentration in the irrigation system and the concentration or strength of the chlorine source.

Liquid sodium hypochlorite is the most convenient and generally safest form of chlorine available to inject into irrigation systems. Stock solutions can be bought with concentrations of 5.25, 10, or 15 percent available chlorine. Table 1 or Equations 1-3 may be used to determine the chlorine solution injection rate in gallons per hour (gph) for different desired ppm injection levels and irrigation system flow rates. Equations 1 - 3 are specific for liquid chlorine injection and are designed for stock solution chlorine concentrations of 5.25, 10, and 15 percent, respectively. For more information on chemical injection, see Haman et al. (2003) and Clark et al. (2005).

Equation 1 can be used to determine the injection rate (gph) of a 5.25% available chorine liquid with ppm referring to the desired chlorine concentration.

$$gph = \frac{(ppm)(Irrigation\_flow\_rate, gpm)}{971}$$

Equation 1.

Equation 2 can be used to determine the injection rate (gph) of a 10% available chorine liquid with ppm referring to the desired chlorine concentration.

$$gph = \frac{(ppm)(Irrigation\_flow\_rate, gpm)}{1850}$$

Equation 2.

Equation 3 can be used to determine the injection rate (gph) of a 15% available chorine liquid with ppm referring to the desired chlorine concentration.

$$gph = \frac{(ppm)(Irrigation\_flow\_rate, gpm)}{2775}$$

Equation 3.

For example, an irrigation system has a flow rate of 500 gpm and the water is to be treated with 8 ppm of available chlorine using a stock solution with 10% available chlorine. Using Equation 2, the injection rate of the stock solution is:

$$\frac{(8\,ppm)(500\,gpm)}{1850} = 2.2\,gph$$

Equation 4.

The same information can be determined using Table 1. For example, a treatment level of 8 ppm with a 10% available chlorine concentration corresponds to an injection rate of 0.43 gph. Note that this is the required injection rate for each 100 gpm. Thus, for 500 gpm, the injection rate would be five times as large, or 2.2 gph.

Another example is provided by equation 5 where a stock solution concentration of 5.25% available chlorine was used with a 500 gpm irrigation system. The goal was to have an 8 ppm active chlorine concentration in the irrigation system:

$$\frac{(8\,ppm)(500\,gpm)}{971} = 4.1\,gph$$

Equation 5.

Calculations can also be completed for the same scenario illustrated in equation 5 using information from Table 1. For a treatment level of 8 ppm and a 5.25% available chlorine source concentration, the corresponding injection rate of 0.82 gph per 100 gpm of irrigation flow rate can be read from Table 1. The chlorine injection rate for a 500 gpm irrigation system would be five times as large as the 100 gpm value, or 4.1 gph.

Some chemical injection pumps may not provide settings low enough to deliver the estimated chlorine rates to the irrigation system. In these cases, the chlorine stock solution can be diluted with water. A 10% chlorine stock solution could be diluted with 1 part water and 1 part 10% chlorine solution to create a

5% available chlorine solution. Likewise, a 10% stock solution can be diluted with 4 parts water and 1 part 10% chlorine solution to make a 2% available chlorine solution. Injection pumps should also be calibrated before use and periodically during use to determine actual injection rates. For more information on injection pump calibration see Chemigation Equipment and Techniques for Citrus (Boman et al., 2004).

Continuous, intermittent, and shock treatments

Chlorine may be injected using different management strategies depending on the desired outcome. Continuous chlorine treatments may be injected at very low concentrations to maintain a clean system. Intermittent injection of chlorine would be at a higher concentration than continuous injection. Continuous and intermittent injections are considered a preventative maintenance measure. Alternatively, a shock treatment would be at a very high concentration (>50 ppm) and be considered a corrective measure.

Injection of chlorine using continuous treatments should occur after the irrigation system has been pressurized. For intermittent or shock treatment a different process is advised. For this method, flush irrigation lines by pressurizing the system and alternating opening different lines to obtain a vigorous flush. This would be followed by a chlorine injection with irrigation. The chlorine should be allowed 30 to 60 minutes of contact time in the irrigation lines; the lines should then be flushed with irrigation water (see Smajstrla and Boman, 2002).

Plant Sensitivities

A critical consideration when using chlorine to clean irrigation systems is the sensitivity of the irrigated crop to chlorine. Some crops that have been shown to be sensitive to chloride are starch potatoes, tomatoes, tobacco, strawberries, peppers, cucumber, melon, lettuce, and flowers and ornamentals (Sartain and Kruse, 2001; KALI, 2009).

Summary

The sources of chlorine used to treat water for microorganisms include chlorine gas, powder or tablets of calcium hypochlorite (pool bleach), and liquid sodium hypochlorite (laundry bleach). The concentration of available chlorine ranges from 5.25-15% in liquid sodium hypochlorite. Therefore, the amounts of these products to be injected will depend on the stock solution concentration used. The user should check with the chlorine supplier to ensure that the material is labeled for injection into irrigation systems. In addition, safety and proper backflow prevention are always required when injecting chemicals into an irrigation system.

Related References

Boman, B. J. 2002. Chapter 36, Prevention of Emitter Clogging. In Water and Florida Citrus: Use, regulation, irrigation, systems, and management. University of Florida Institute of Agricultural and Food Sciences: Gainesville, FL.

Boman, B., S. Shukla, and D. Haman. 2004. Chemigation equipment and techniques for citrus. (IFAS Publication CIR1403), Florida Cooperative Extension Service. Gainesville, FL. http://edis.ifas.ufl.edu/CH184

Clark, G. A., D. Z. Haman and F. S. Zazueta. 2005. Injection of Chemicals into Irrigation Systems: Rates, Volumes, and Injection Periods. (IFAS Publication BUL 250), Florida Cooperative Extension Service. Gainesville, FL. http://edis.ifas.ufl.edu/AE116

Haman, D.Z., A.G. Smajstrla, and F.S. Zazueta. 2003. Chemical Injection Methods for Irrigation. (IFAS Publicaion CIR864), Agricultural and Biological Engineering, Florida Cooperative Extension Service, Gainesville, FL. http://edis.ifas.ufl.edu/WI004

KALI, 2009. Chloride tolerance of variance crops. Website: http://www.kali-gmbh.com/r021en/fertiliser/advisory_service/chloride_tolerance.html Accessed: May 5, 2009.

Nakayama, F.S., B.J. Boman, and D.J. Pitts. 2007. Chapter 11, Maintenance. In Microirrigation for Crop Production: Design, Operation, and Management. Elsevier.

Nakayama, F. S. and D. A. Bucks. 1986. Trickle Irrigation for Crop Production: Design, Operation, and Management. Elsevier. Amsterdam. 383 p.

Pitts, D. J., D. Z. Haman and A. G. Smajstrla. 2003. Causes and Prevention of Emitter Plugging in Micro Irrigation Systems. (IFAS Publication BUL 258), Florida Cooperative Extension Service, Gainesville, FL. http://edis.ifas.ufl.edu/AE032

Sartain, J.B. and J.K. Kruse. 2001. Selected Fertilizers Used in Turfgrass Fertilization. (IFAS Publication CIR 1262), Soil and Water Science Department, Florida Cooperative Extension Service, Gainesville, FL. http://edis.ifas.ufl.edu/SS318

Smajstrla, A. G., D. S. Harrison, W. J. Becker, F. S. Zazueta and D.Z. Haman. 1991. Backflow Prevention Requirements for Florida Irrigation Systems. (IFAS Publication BUL 217), Florida Cooperative Extension Service. Gainesville, FL.

Smajstrla, A. G., D. Z. Haman and F. S. Zazueta. 1992. Calibration of Fertilizer Injectors for Agricultural Irrigation Systems. (IFAS Publication CIR1033), Florida Cooperative Extension Service. Gainesville, FL.

Table 1. Liquid chlorine (sodium hypochlorite) injection rates.

Treatment Level (ppm)	Concentration of available chlorine in stock solution (percent)						
	1	2	3	4	5.25*	10*	15*
(gph of injection per 100 gpm of irrigation flow rate)							
1	0.54	0.27	0.18	0.14	0.10	0.054	0.036
2	1.1	0.54	0.36	0.27	0.21	0.14	0.072
3	1.6	0.81	0.54	0.41	0.31	0.16	0.11
4	2.2	1.1	0.72	0.54	0.41	0.22	0.14
5	2.7	1.4	0.90	0.7	0.51	0.27	0.18
6	3.3	1.7	1.1	0.8	0.62	0.32	0.22
8	4.4	2.2	1.5	1.1	0.82	0.43	0.29
10	5.5	2.8	1.8	1.4	1.0	0.54	0.36
15	8.3	4.1	2.8	2.1	1.5	0.81	0.54
20	11.0	5.5	3.7	2.8	2.1	1.1	0.72
25	13.8	6.9	4.6	3.4	2.6	1.4	0.90
30	16.5	8.3	5.5	4.1	3.1	1.6	1.1
40	---	11.0	7.3	5.5	4.1	2.2	1.5
50	---	13.8	9.2	6.9	5.2	2.8	1.8
75	---	---	13.8	10.3	7.7	4.1	2.8
100	---	---	---	13.8	10.3	5.5	3.7

*These are commercially available concentrations. Other concentrations are obtained by diluting with water.