CIR1039

Treating Irrigation Systems with Chlorine [1]

Gary A. Clark and Allen G. Smajstrla[2]

Chlorine is used in many water supply systems and home swimming pools to prevent algae and other microorganisms from growing. Chlorine is also used for cleaning and maintaining irrigation systems. Proper injection methods and amounts of chemical must be used to provide an effective water treatment program without damaging the irrigation system or the crop being grown. Because chlorine can react with some metals and plastics, always check with the manufacturer of your irrigation system components to make sure that problems will not occur if chlorine is injected.

Irrigation systems can become partially or completely clogged from biological growths of bacteria, fungi, or algae which are often present in surface and ground water. Bacteria, fungi, and algae use chemical elements such as nitrogen, phosphorus, sulfur, or iron as nutrient sources to grow and develop. Generally, filtration alone cannot effectively remove these microorganisms. Chlorination can be used to minimize the growth of microorganisms within the pipes and other components of irrigation systems.

If water is not properly treated, clogging of pipes, fittings, and emission devices (sprinklers, drippers, spray jets, etc.) can occur, resulting in decreased crop growth and development because of reduced water application amounts, uniformity, and efficiency. This publication provides information on sources of chlorine and the amounts required for treating irrigation water and systems to control the growth of microorganisms.

Sources of Chlorine

Chlorine is available in gas, liquid, and solid (granular or tablet) forms. However, only the liquid form (liquid sodium hypochlorite) has an Environmental Protection Agency (EPA) special local need (SLN) label for use as a pesticide in irrigation systems in Florida. All pesticides or other chemicals should be injected into irrigation systems only as directed on the chemical labels. Also, all label directions must be followed to ensure that the chemicals will be safely applied.

Each of these three different chlorine forms reacts differently with the irrigation water, depending on the other chemicals or elements in the water. Reactions may be changes in the pH of the water, or

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 2006. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
2. Gary A. Clark, Associate Professor of Biological and Agricultural Engineering, Kansas State University, Manhattan, KS (formerly Extension Irrigation Specialist, Gulf Coast Research and Education Center, Bradenton, FL, University of Florida); and Allen G. Smajstrla, Professor, Agricultural and Biological Engineering Department; Reviewed by D.Z. Haman; Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

precipitation of some element which could result in clogging of microirrigation components.

Chlorine Gas

Chlorine gas (Cl_2) 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 irrigation water. The change in pH depends on how much chlorine gas is injected and on the buffering capacity of the water.

Chlorine gas is used in municipal water treatment systems because it provides chlorine in the most concentrated and economical form. Only 1 pound (lb) of chlorine gas (Cl_2) is required to provide a 1 ppm concentration of $C1_2$ 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 2000 gallons per minute (gpm).

Chlorine gas 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 1000 ppm. Therefore, the user of chlorine gas must exercise extreme caution to ensure that it is safely injected. 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. This form of chlorine is commonly used in municipal water treatment systems. Its use should be limited to experienced or licensed users.

To ensure safety, manufacturers have developed chlorine gas injectors 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.

Solid Chlorine

Granular (powdered or tablet) forms of chlorine are commonly used to chlorinate swimming pools. Calcium hypochlorite found at local swimming pool supply stores is the form that is typically used. 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.

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. Thus, approximately 1.5 lb of calcium hypochlorite will treat 1,000,000 lb (120,000 gallons) of water with a 1 ppm concentration of $C1_2$.

Calcium hypochlorite may react with other elements in irrigation water to form precipitates which could clog microirrigation emitters and thus defeat the purpose for chlorination. Thus, liquid chlorine (sodium hypochlorite) rather than solid calcium hypochlorite should be used in irrigation systems, especially when the water source is high in minerals, such as when water from the Floridan aquifer is used.

Liquid Chlorine

Liquid sodium hypochlorite is most commonly used as laundry bleach. However, it also has an EPA special local need label for use in irrigation systems in Florida. 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. Unlike the calcium added in the solid chlorine form, the sodium added in this liquid form does not contribute to clogging problems. Neither the sodium nor the chlorine added to the water would be detrimental to crops or soils at the typical low concentrations used.

Effects of Chlorine

Hypochlorous acid (HOCl) is the effective agent 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). At pH 8, only about 22% of the chlorine injected will be in the active HOCl form, at pH 7, about 73% will be in the HOCl form, and at pH 6, about 96% will be in the HOCl form (Nakayama and Bucks, 1986). Thus, if the irrigation water pH is high (as is often the case when pumping from the Floridan aquifer), the effectiveness of chlorine may be enhanced by injecting an acid to reduce the pH of the water before injecting chlorine (Kidder and Hanlon, 1985). In addition to increasing the effectiveness of chlorine, acid injection can also prevent the precipitation of minerals which may plug microirrigation systems. However, it is normally only necessary to reduce the pH one or two units to achieve these desirable benefits. Procedures for calculating the amount and form of acid to inject were given by Kidder and Hanlon (1985).

At extremely low pH levels (or high acidity) chlorine gas (Cl_2) will form. Therefore, for safety, it is very important to store chlorine and acid sources separately. Also, storage and use areas should be well-ventilated so that gasses cannot concentrate and become a hazard in a building or other enclosed area.

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.

Hypochlorous acid will react with iron in solution to oxidize the ferrous iron to the ferric form. The ferric iron then becomes the insoluble ferric hydroxide as a precipitate. Chlorine should be injected before (upstream from) the filters so that these precipitates may be trapped in the filters.

Chlorine will also react with hydrogen sulfide to form elemental sulfur. Because some of the chlorine is used up by reacting with the sulfide or ferrous ions, additional chlorine must be provided for these reactions to occur. Enough residual chlorine must be injected to control sulfur or iron bacteria, or algae, which can clog microirrigation systems.

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. 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 D.P.D. 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 D.P.D. test kit from either a swimming pool or irrigation supply company.

Chlorine Application Amounts

After determining the desired chlorine concentration, 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 (equation 1 , equation 2 , equation 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 a 5.25% available chlorine stock solution:(equation 1)

$$Injection\ Rate_{5.25\%},\ gph = \frac{(ppm)(Irrigation\ Flow\ Rate,\ gpm)}{971} \quad (1)$$

equation 1.

$$Injection\ Rate_{10\%},\ gph = \frac{(ppm)(Irrigation\ Flow\ Rate,\ gpm)}{1850} \quad (2)$$

equation 2.

$$Injection\ Rate_{15\%},\ gph = \frac{(ppm)(Irrigation\ Flow\ Rate,\ gpm)}{2775} \quad (3)$$

equation 3.

For a 10% available chlorine stock solution:(equation 2)

For a 15% available chlorine stock solution: (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 should be (equation 4):

$$\frac{(8\ ppm)(500\ gpm)}{1850} = 2.2\ gph \quad (4)$$

equation 4.

Or, from Table 1 , for a treatment level of 8 ppm and a 10% available chlorine concentration, read 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.

If the stock solution concentration was 5.25% available chlorine, then the injection rate should be (equation 5):

$$\frac{(8\ ppm)(500\ gpm)}{971} = 4.1\ gph \quad (5)$$

equation 5.

Or, from Table 1 , for a treatment level of 8 ppm and a 5.25% available chlorine concentration, read an injection rate of 0.82 gph per 100 gpm of irrigation flow rate. Then for 500 gpm, the injection rate would be five times as large, or 4.1 gph.

If the injection rate calculated is too small for the injection pump to be used, the chlorine stock solution can be diluted with irrigation water. Thus, if the 10% stock solution was diluted with 1 part water and 1 part 10% chlorine solution, the new stock solution would be diluted by 1/2. It would have 5% available chlorine, assuming that the water added did not tie up any of the available chlorine. Likewise, if the 10% stock solution was diluted with 4 parts water and 1 part 10% chlorine solution, the new stock solution would be diluted by 1/5, and it would have 2% available chlorine.

Safety

Chlorine is a powerful oxidizing agent and it must be handled carefully. A fresh water source should be available at the field site where liquid sodium hypochlorite is being used so that any contact or spills can immediately be washed off. Protective clothing should be worn while handling this chemical and injectors. Goggles should be worn to protect eyes against splashes.

Chlorine gas is a respiratory irritant which affects the mucous membranes. It can be **fatal** after a few breaths at 1000 ppm. Therefore, users of chlorine gas must exercise **extreme caution** to ensure that it is safely injected. 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. This form of chlorine is commonly used in municipal water treatment systems. It should only be used by experienced or licensed users. For safety, only vacuum type injectors should be used.

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).

However, only liquid sodium hypochlorite is labeled for use in irrigation systems in Florida. 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

Clark, G. A., A. G. Smajstrla, D. Z. Haman and F. S. Zazueta. 1990. Injection of Chemicals into Irrigation Systems: Rates, Volumes, and Injection Periods. Bulletin 250. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

Ford, H. W. 1979. The Use of Surface Water for Low Pressure Irrigation Systems. Fruit Crops Mimeo Report FC79-1. Univ. Fla., Lake Alfred.

Ford, H. W. 1979. The Present Status of Research on Slimes of Sulfur in Low Pressure Irrigation Systems and Filters. Fruit Crops Mimeo Report FC79-2. Univ. Fla., Lake Alfred.

Ford, H. W. 1979. The Present Status of Research on Iron Deposits in Low Pressure Irrigation Systems. Fruit Crops Mimeo Report FC79-3. Univ. Fla., Lake Alfred.

Ingram, D. and B. Hoadley. 1986. Chemical Injection for Drip Irrigation in the Woody Ornamental Nursery. Ornamental Horticulture Commercial Fact Sheet OHC-6. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

Kidder, G. and E. A. Hanlon. 1985. Neutralizing Excess Bicarbonates from Irrigation Water. Notes in Soil Science No. 18. Soil & Water Science Dept., Univ. Fla., Gainesville.

Kovach, S. P. 1984. Injection of Fertilizers into Drip Irrigation Systems for Vegetables. Circular 606. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

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. 1990. Causes and Prevention of Emitter Plugging in Micro Irrigation Systems. Bulletin 258. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

Smajstrla, A. G., D. S. Harrison, W. J. Becker, F. S. Zazueta and D.Z. Haman. 1991. Backflow Prevention Requirements for Florida Irrigation Systems. Bulletin 217 (revised). Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

Smajstrla, A. G., D. Z. Haman and F. S. Zazueta. 1992. Calibration of Fertilizer Injectors for Agricultural Irrigation Systems. Circular 1033. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

Yeager, T. H. 1986. Fertigation Management for the Wholesale Container Nursery. Bulletin 231. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

Yeager, T. H. and R. W. Henley. 1987. Techniques of Diluting Solution Fertilizers in Commercial Nurseries and Greenhouses. Circular 695. Fla. Coop. Ext. Ser., Univ. Fla., Gainesville.

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.