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Chlorine is an affordable option that is the most widely used chemical for water sanitation.

By Paul Fisher, Jinsheng Huang, Austin Looper, Dave Minsk, Bill Argo, Rick Vetanovetz and Youbin Zheng

Water treatment series: Water sanitation using chlorine

CHLORINE CAN BE USED to kill pathogens, bacteria that are harmful to human consumption, as well algae and iron-forming bacteria that clog filters and nozzles. Chlorine also provides residual protection by treating water as it travels through the irrigation system and out into the greenhouse or nursery.

Forms of chlorine

There are solid (calcium hypochlorite), liquid (sodium hypochlorite) and gas forms of chlorine. All three forms deliver hypochlorous acid (HOCl), which is the sanitizing form of chlorine, upon dissolution in water. This article provides some guidelines on how to treat water with chlorine, focusing on the liquid sodium hypochlorite (i.e., bleach) and solid calcium hypochlorite (i.e., tablets) forms.

Dosing chlorine

Chemicals containing chlorine can simply be dosed into the irrigation water using volumetric proportion. A specific initial dose (e.g., 5 parts per million) is provided at the well head, to ensure adequate residual (typically 0.5 to 2 ppm) at the outlet. The difference between the initial and residual concentration is termed "chlorine demand."

The treatment system is most effective if the irrigation water quality (chlorine demand) remains constant. If the pH, biological load or temperature never change then the dosing ratio can be determined using a simple chlorine meter.

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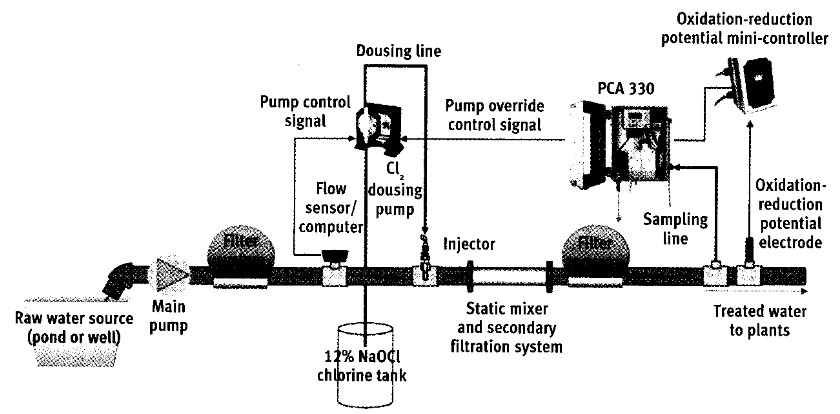
Greenhouse uses liquid bleach to treat water

Sodium hypochlorite system



Michael's Greenhouses in Cheshire, Conn., operates 5 acres of greenhouses and 15 acres of outside growing area. The company produces plants year-round to sell to garden centers.

Several years ago, a large water storage tank was installed to increase water availability during peak irrigation times. Michael's well water was contaminated with iron bacteria. The bacteria clogged the boom irrigation nozzles, severely damaging plant quality and increasing labor costs.

A Hanna Instruments chlorination system was installed to dose sodium hypochlorite (bleach) into a circulating loop in the water storage tank. The system included an oxidation-reduction potential (ORP) controller, probes, chlorine injector and a process chlorine analyzer (PCA).

Chlorine is injected into the tank via the circulating loop, the oxidation-reduction potential is maintained at 650 milli-volts (mV), and oxygen is also pumped into the tank. This system has dual safety controls, including metering the chlorine via oxidation-reduction potential and a second control based on chlorine concentration.

The chlorination system has provided clean irrigation water, with reduced algae growth and no clogged nozzles. The cost to treat Michael's water is about $40 per year for chlorine bleach. This low cost resulted from the synergistic benefit of aeration, filtration and controlling the chlorine injection via oxidation-reduction potential.

For more: Michael's Greenhouses Inc., (203) 272-4680; www.michaelsgreenhouses.com.

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Simple dosing is less effective when water has a fluctuating chlorine demand, which applies to a majority of greenhouse watering systems.

Factors that increase chlorine demand include:

- Warm weather.
- Use of recycled or pond water.
- Accumulation of fertilizers, peat and plant debris in the irrigation water.
- Biofilm and algae.

Chlorine demand

The mode of action of hypochlorous acid is through oxidation and chlorination of many types of organic material, and not just pathogens or algae. To make the addition of hypochlorous acid more effective for pathogen control, prefilter water to remove excess organic material.

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Tips for using sodium and calcium hypochlorite

1. Chlorine should be combined with other water treatment components such as filtration and aeration to increase efficacy.

2. Store liquid sodium hypochlorite protected from ultraviolet light, either at low temperatures (60°F-70°F) or in smaller volumes so that it is turned over in 15 days (degradation rate doubles for each 10°F temperature increase).

3. Store solid calcium hypochlorite in a dry location.

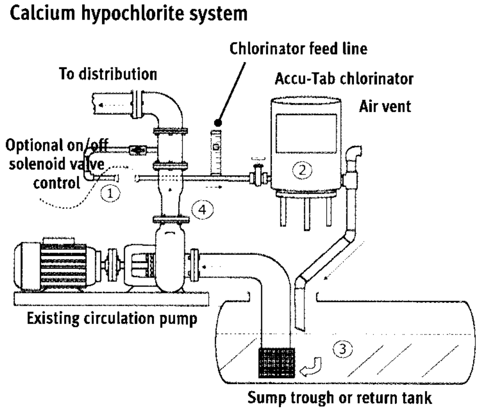
4. At the low chlorination rates (below 2 ppm) used for constant treatment, sodium, calcium or chlorine will not significantly affect plant nutrition, water electrical conductivity, calcium deposits or pipe corrosion. However, when handling concentrated chlorine, use injectors and piping designed for caustic chemicals.

5. Because chlorine can react with some metals and plastics, check with the manufacturer of your irrigation system components to make sure that problems won't occur if chlorine is injected.

6. Follow guidelines for operator safety and handling. Never mix concentrated chlorine with other chemicals.

Using calcium hypochlorite for chlorination

Calcium hypochlorite system



1. When the pump starts, water from the sump is pumped into the discharge line. The solenoid opens and a small side stream of pressurized water flows through the chlorinator feed line, flow meter, and control valve.
2. The water contacts the Accu-Tab tablets in the chlorinator and erodes a controlled, predictable amount of chlorine.
3. The chlorinated water drains next to the pump suction and is immediately pulled into the pipe and thoroughly mixed.
4. Treated water is pumped into the distribution network. When the pump stops, the solenoid valve closes and the chlorinator stops. The control valve allows precise chlorine residual control: high flow rates for "shock" treatments or lower flow rates for maintenance chlorination.

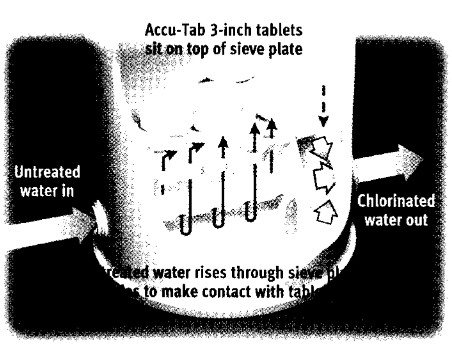


Diagram of a calcium hypochlorite chlorinator

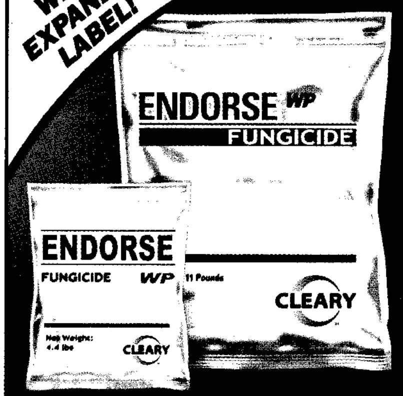
A nursery wants to control *Phytophthora* in its irrigation water, which is pulled from a surface pond. Water was pumped from the pond six hours per day at 550 gallons per minute. The company installed a water-treatment system that dosed chlorine using calcium hypochlorite tablets.

The Accu-Tab System chlorinator consists of a rigid PVC cylinder with a sieve plate resting above the bottom of the unit. Incoming water from a side stream contacts only the tablets at the bottom of the feeder, so remaining tablets stay dry and don't dissolve prematurely.

The tablets dissolve at a predictable rate dependent upon water flow to the unit. Chlorine dosage is controlled by the water flow rate through the chlorinator. The chlorinator effluent is then returned to the un-chlorinated main system flow providing the desired level of available chlorine.

The chlorinator installed by the nursery holds 75 pounds of tablets, which are recharged weekly. The system also includes a flow meter, gate valve, chlorinator, saddle clamp and PVC pipe costing a total of $1,005 including the chlorinator and installation. The system had no moving parts and low maintenance. This application did not require electricity or additional sensors, but the chlorinator could be controlled via oxidation-reduction potential and inline sensors if preferred.

To calculate operational cost of the system, it is necessary to determine how much chlorine is going to be used by the calcium hypochlorite chlorinator. Published literature indicates that maintaining 2 ppm free chlorine residual in the line inactivates multiple species of *Phytophthora*. However, more than 2 ppm must be injected since surface water has some demand in the form of organic material and algae. Surface water demand fluctuates between 2-5 ppm chlorine with the season. Using an average of 3.5 ppm demand plus 2 ppm residual requires a total of 5.5 ppm. The cost to generate this much chlorine would be 17 cents per 1,000 gallons of treated water.



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Fluctuating chlorine demand of the water system affects the amount of chlorine that needs to be initially dosed to provide a consistent residual level. Research at the University of Guelph showed that maintaining 2 ppm of free chlorine for five minutes can control most common plant pathogens. However, biological load varies with temperature and tends to increase during spring and summer, especially with surface or recycled water sources. Higher temperatures require more chlorine injection to combat algae and pathogen growth. Seasonal fluctuations in water alkalinity or pH can also change the chlorine demand because the concentration of hypochlorous acid decreases as pH increases.

Consistent and simple chlorine dosing without adequate control of residual chlorine concentration can be harmful to plants. If chlorine demand suddenly drops (for example, because of cold weather), then residual chlorine can rise to phytotoxic levels (typically above 4 ppm hypochlorous acid for short term exposure and 2 ppm for long-term exposure). If chlorine demand increases, hypochlorous acid level may be inadequate to control pathogens. Overdosing or release of gas into the air (off-gassing) at very low pH are potential worker safety hazards.

Oxidation-reduction potential

Volumetric injection and measurement of chlorine concentration can be combined with the measurement of oxidation-reduction potential (ORP). Oxidation-reduction potential is read in milli-volts (mV) and measures the oxidative power of the treated water. Oxidation-reduction potential is a proven technology for municipal water treatment and food safety.

An oxidation-reduction potential level of 650 to 750 milli-volts is typically used to indicate adequate sanitation based on killing of human pathogens. Research is ongoing to refine oxidation-reduction potential levels suited for plant production.

Control using chlorine and oxidation-reduction potential is ideally undertaken with inline sensors and dosage systems. This method of control can be applied to dosage of all chlorine forms (gas, liquid and solid), as well as some other oxidizing chemicals. An additional controller for water pH is also needed where water is acidified.

In a low-tech installation without inline controls, water pH and free chlorine can be measured weekly using calibrated handheld meters. Handheld oxidation-reduction potential meters are also available.

At the University of Florida, tests with commercially available Extech oxidation-reduction potential and chlorine meters and a Hanna Instruments oxidation-reduction potential meter have yielded results similar to a higher-cost laboratory sensor.

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Chemical names and trade names are included as a convenience to readers and to illustrate examples of chlorine technologies. The use of brand names and any mention or listing of commercial products or services does not imply endorsement by the University of Florida, nor discrimination against similar products or services not mentioned.

Individuals who use chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage and examine a current product label before applying any chemical. For assistance, contact your state pesticide regulating authority.