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199. Water treatment series: choose the best water-treatment method for your operation. Fisher, P., Argo, W., Fischer, R., and Konjoian, P. Greenhouse Management and Production 28(3):19, 21-24. 2008.

Choosing the best water treatment method for a particular greenhouse can be confusing. This 12-part series presented by the new Water Education Alliance for Horticulture aims to assist growers in making effective water-treatment decisions.

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Water treatment series: Choose the best water-treatment method for your operation

OVER THE LAST TWO YEARS many parts of the continent have experienced problems with water quantity or quality. Water is a major issue for horticulture. Drought conditions and water restrictions in the Southeast are forcing companies to adapt or go out of business. With increasing urbanization, water-management authorities are regulating supply and runoff as growers and landscapers compete with both rising consumer and commercial water demands.

Growers recognize the importance of water conservation and recycling. However, the potential spread of waterborne pathogens in irrigation water has also highlighted the need to treat and manage water quality, especially in recycled water. Choosing the best water treatment method can be confusing.

Water treatment is an area of emerging technologies and innovation, with gaps in our industry's current knowledge. Water treatment for horticulture involves perspectives of water chemistry more common to the swimming pool and municipal treatment industries than horticulture, in addition to plant pathology, engineering and financial analysis.

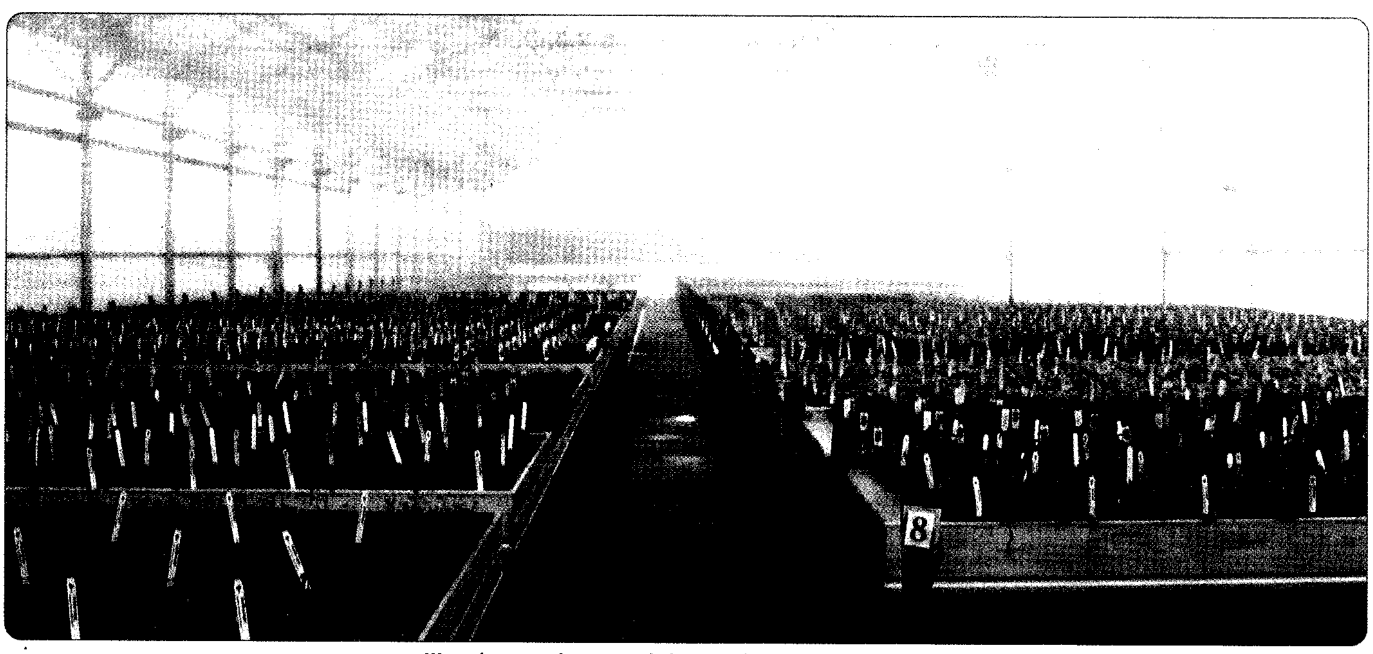
Define goals and priorities

The goal for water treatment is not to sterilize the system. This is unrealistic and undesirable because many microorganisms are beneficial or benign. The real goal is to minimize the pathogen risk from water as part of an overall sanitation program — without blowing the grower's budget.

Systems approach

A big-picture perspective is required to evaluate the overall flow of water in an operation. A water-treatment specialist can help to identify the potential points of contamination that can lead to the correct combination of technologies needed.

There is no one silver bullet when it comes to water treatment. Many technologies work. The questions



Water-borne pathogens and algae can be an issue under moist propagation conditions, especially with recirculating irrigation systems.

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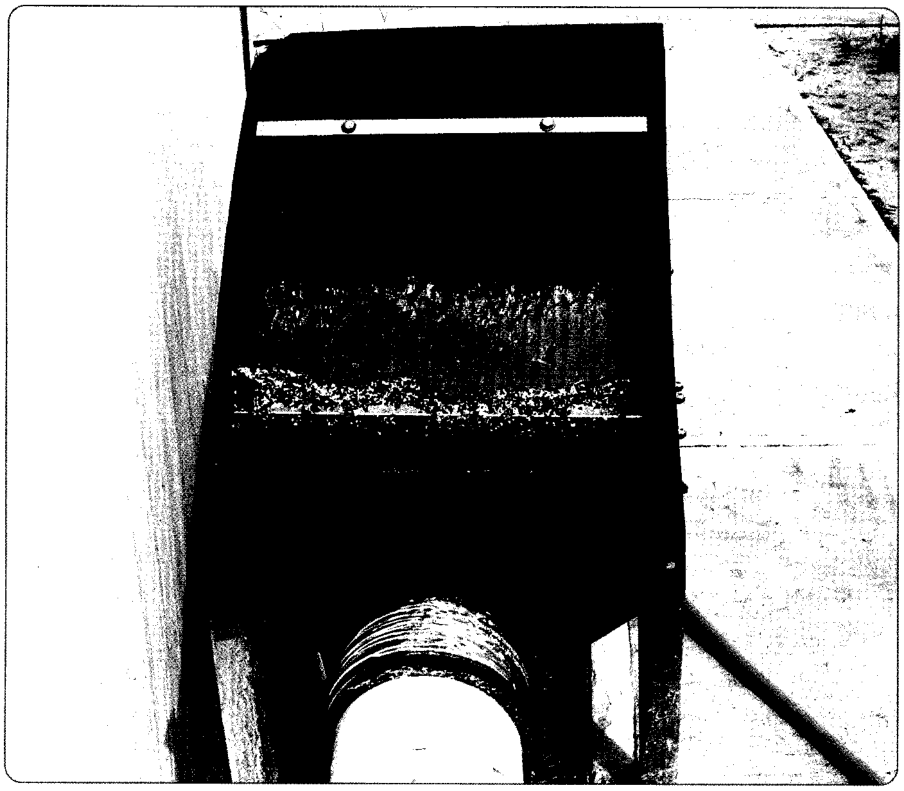

A coarse filter was installed at this greenhouse. A finer filtration system is recommended to improve effectiveness of ultraviolet light and other treatment methods.

that need to be answered are which are the most cost-effective, how do they interact and how can they be used effectively?

Filtration

Filtration and water pretreatment underlies all other treatment technologies. Treatments such as ultraviolet light require clear water for wavelengths to penetrate pathogen cell walls. Oxidizing materials such as chlorine will react to any organic material, whether it is peat or a pathogen cell wall, and are therefore less effective in the presence of

Notes on water treatment options

Desired concentration depends on the application. See product label and manufacturer's instructions for specifics.

All treatment methods mentioned are nonspecific and react with any type of organic matter, whether it is a pathogen, algae or a particle of peat. In all cases, the cleaner the water is before the treatment, the more effective the disinfection method is at removing pathogens.

Bromine, chlorine products, ozone, peroxyacetic acid and hydrogen peroxide are strong oxidizing agents. Metal micronutrients (copper, iron, manganese and zinc) are easily oxidized (particularly iron). It is likely that long-term exposure (over 20 minutes) of metal micronutrients to these oxidizing agents will decrease their solubility. Chelated micronutrients should only be slightly less affected than sulfates.

Ultraviolet radiation is a photo-oxidizing agent. Studies by Cornell University researchers on photo-oxidation of iron in fertilizer solutions indicates that the greater the light exposure, the less iron that will remain in solution.

Quaternary ammonium compounds such as Green-Shield, Physan 20 or Triathlon are listed for disinfection of walkways, benches, tools and flats, but are not for use with irrigation water.

Liquid hydrogen peroxide/hydrogen dioxide (H_2O_2) solutions (35-50 percent H_2O_2) are not U.S. EPA-registered for water treatment in greenhouses. H_2O_2 solutions are less effective and stable compared with registered activated peroxygen products.

Treatment options for waterborne pathogens in greenhouse irrigation systems

Chemical	Active ingredient	Readily soluble	Injection method	How they work	Usual range in concentration	Notes
Bromine (i.e., Agribrom)	1-Bromo-3-chloro-5,5-dimethyl-2,4-imadazolidin-edione	No	Tablets or granules are placed in a container with water. The supernatant solution is injected into the irrigation water.	Oxidizing agents listed in this table interact with reactive chemical groups on organic matter. The oxidation of organic matter results in a change in the chemical structure of the organic matter and the death of the pathogens. The oxidizing agent itself is also "used up" during sanitation because the agent changes chemical form as it reacts with organic matter. Pathogens vary in their susceptibility to the agents listed in this table, and the required concentration of oxidizing agent therefore also varies. The material being oxidized can include pathogens, peat and fertilizer salts. Good pre-filtration is essential because all organic matter in the water absorbs and depletes oxidizers.	5 to 35 parts per million bromine	Because of low solubility, some time is required for the undissolved tablets or granules to replenish the bromine in the stock solution. Difficult to maintain a constant concentration of bromine over the course of the day, especially with high flow rates. Requires a special injector resistant to corrosive chemicals.
Chlorine gas	Cl_2	Yes	Chorine gas is bubbled through the water, where it combines with the water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl).			Hazardous gas requires special equipment, ventilation, and handling. As with all chlorine application methods, higher than recommended concentrations can be toxic to plants.
Sodium hypochlorite	NaOCl	Yes	Liquid NaOCl solutions (5-15% chlorine) are injected directly into irrigation water.		0.5 to 2 ppm free chlorine. Hypochlorite is a weak acid and can be found in solution in 2 different forms, OCl- and HOCl. Because the HOCl form is much more effective at disinfecting than the OCl- form, the water pH should be controlled, as sanitizing reactions tend to be slower at higher pHs.	Requires a special injector that is resistant to very corrosive chemicals and has a very high injection ratio. Has a limited shelflife. High temperatures and sunlight speed up breakdown. Never combine with fertilizers or other chemicals containing ammonium.
Calcium hypochlorite	$Ca(OCl)_2$	Yes	Granules may be dissolved in water or tablets can be eroded in a flow-through feeder for more automatic chlorination, at chlorine concentrations up to 10,000 ppm, depending on the feeder and operating conditions.			Calcium hypochlorite solutions of up to approx. 21% can be prepared, but due to the presence of insoluble materials such as calcium carbonate solutions of above 200 ppm tend to be cloudy. Sediment forms with very concentrated solutions. At less than 100 ppm available chlorine there should be no apparent cloudiness or sediment.
Chlorine dioxide (i.e., Ultra-Shield, Selectrocide)	ClO_2	Yes	Dry packet or tablets placed in water, ClO_2 solution generated in stock tank.		Injected into irrigation lines. Continuous injection of residual concentration of 0.25 ppm or less. Twice a year shock treatment at 20-50 ppm depending on product.	Stock solution should be used within 15 days to minimize loss due to volatilization. Maximum stock concentration of 500 or 3,000 ppm depending on product.
Ozone	O_3	No	An electrical arc is used to produce the ozone from bottled or atmospheric oxygen. The ozone is then bubbled through the water.		Residual effect from reaction products (peroxides, organic radicals). Breaks up biofilm. 10 grams/hour/cubic meter.	Requires professional design based on water analysis. Proper design prevents ozone from escaping into the atmosphere in hazardous concentrations.
Activated peroxygen (i.e., ZeroTol, SaniDate)	Hydrogen dioxide/hydrogen peroxide (H_2O_2) and Peroxyacetic acid/peracetic acid CH_3COO-OH	Yes	A stabilized H_2O_2 and peracetic/peroxyacetic acid solution that is injected directly into irrigation water. Peroxyacetic acid is a more effective biocide than H_2O_2 alone.		27-540 ppm H_2O_2	Requires a special injector that is resistant to very corrosive chemicals and has a very high injection ratio or the material must be diluted before injection.

Treatment options for waterborne pathogens in greenhouse irrigation systems (continued)

Chemical	Active ingredient	Readily soluble	Injection method	How they work	Usual range in concentration	Notes
Ultraviolet radiation		Not applicable	Water is exposed to high doses of UV light in tubular chambers. Most common are low pressure mercury vapor lamps with a wavelength of 254 nanometers, close to the optimum range for killing pathogens.	UV radiation disrupts the genetic material in the cell, effectively killing it. Dose, exposure time and turbidity determine effectiveness.	250 millijoules per square centimer eliminates most pathogens. No residual effect on pathogens downstream of treatment.	The effectiveness of the lamp decreases with age. Any particulate matter n the water will disperse the light, making the application of UV radiation less effective. Good pre-filtration is essential. Often used with another disinfecting material to get some residual effect.
Copper ionization	Cu^{++}	Yes	An electrical charge is passed between copper bars or plates releasing copper ions into the water.	Copper ions are a toxin to most pathogens, including *Pythium*, *Phytophthora*, *Xanthomonas* and algae. Recent advances in controls produce consistent copper levels and reliable results.	0.5-1 ppm copper for pathogens. 1-2 ppm for algae and biofilm.	Less effective if water pH is above 7.5. Choose a system which actively controls copper output according to flow and electrical conductivity. Applied copper concentrations are within U.S. drinking water standards and a fraction of plant toxicity levels.
Heat treatment/ Pasteurization		N/A	Water is heated to a specific temperature and waste heat is recovered to pre-heat incoming water.	Pathogen resistance to heat varies. Effect largely independent of water quality.	An example treatment is 203°F for 30 seconds. No residual effect on pathogens downstream of treatment.	High energy use makes it expensive for large flow. To prevent scaling of heat exchangers from hard water, pH needs to be reduced to 4.5, then raised again as needed for irrigation. Best for low flow, high sanitation applications.

Chemical names and trade names are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services does not imply endorsement, 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. Exact data are lacking on the rates (parts per million) of each control product needed to kill different life stages for all pathogens encountered in a production operation.

growing media and plant debris. This series will explain treatment methods ranging from reverse osmosis that removes "almost everything," including all pathogens, to options such as screen, sand and media filters.

Water pH and electrical conductivity

Chemical characteristics of the water source affect most treatment technologies. For example, if the water electrical conductivity is low, then a copper ionization would need to be engineered correctly to increase the copper electrode surface area in order to provide the desired parts per million of copper. If the water pH is above 7.0, using chlorine may require acid injection for pH control.

Technologies available

Many water-treatment options are available (see table on Page 22). The challenge is to decide which one is best for your setup. Specific details on each of these technologies will be provided in upcoming articles.

Some equipment, such as copper ionization, ultraviolet light and ozone, have high initial investment costs, but operating costs are low and they can treat large water volumes cost-effectively. Other injectable materials such as chlorine dioxide have low initial investment costs, but have a higher operating cost and may be better suited for plants that require the highest-quality water.

Treatment considerations

Cost is only one consideration in choosing a water-treatment method. For example, technologies also vary in their mode of action, for example, oxidizers versus toxins. Some treatments, including copper and chlorine, have a residual, downstream effect, whereas other treatments are a single-point treatment. Some

Partnerships lead to water alliance

To help growers make effective water-treatment decisions, University of Florida has partnered with many leading industry and university experts, companies and organizations to form the Water Education Alliance for Horticulture.

Partners in the alliance include TrueLeaf/Aerotech, BioSafe Systems, Griffin Greenhouse and Nursery Supplies, Hanna Instruments, PPG Industries, Whitmire Micro-Gen and the Young Plant Research Center partners.

TrueLeaf/Aerotech workshops on water treatment will be conducted at the OFA Short Course, Plug and Cutting Conference and other events supported by the alliance. Information on these events and additional water treatment resources are available online at the alliance Web site, www.watereducationalliance.org.

materials are designed only for continual low-level treatment, whereas others are also an effective shock treatment to reduce biofilm or are suitable for surface sanitation.

Systems may be combined. An example is the addition of activated peroxygen in conjunction with ozone and/or ultraviolet light increases the sanitizing power of all these technologies.

Flexibility is needed. Increasing levels of bacteria, fungi and algae have been measured as greenhouses operate through winter into spring in response to increasing temperatures, high light levels, increased plant debris and more employee movement. Because of these seasonal variables and periodic disease events, growers may need to increase or decrease water treatment.

Water treatment choices

Water treatment is part of an overall sanitation program. A systems approach is needed to correctly engineer the flow, filtration and treatment. Every application is different. For a specific example of how one greenhouse operation decided to combine treatment technologies, visit the Water Education Alliance for Horticulture Web site, www.watereducationalliance.org.

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