

Table 1. A summary of treatment options for waterborne pathogens in greenhouse irrigation systems.

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Chemical	Active ingredient	Readily soluble	Injection method	How they work	Usual range in concentration ¹	Challenges/Problems
Agribrom™	1-Bromo-3-chloro-5,5-dimethyl-2,4-imadazolidinedione	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.	5 to 35 ppm bromine	Because Agribrom is relatively insoluble, it is difficult to keep a constant concentration of bromine in the irrigation water throughout the day, especially if the flow rate of the irrigation water is not constant.
Chlorine Gas	Cl ₂	Yes	Chlorine gas is bubbled through the water, where it combines with the water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl).		The oxidation of organic matter results in a change in the chemical structure of the organic matter, and death of the pathogen.	0.5 to 2 ppm free chlorine.
Sodium hypochlorite	NaOCl	Yes	Liquid NaOCl solutions (5% to 15% chlorine) are injected directly into irrigation water.	The oxidizing agent itself is also “used up” during sanitation because the agent changes chemical form as it reacts with organic matter.	Hypochlorite is a weak acid and can be found in solution in two different forms, OCl ⁻ and HOCl.	Requires a special injector that is resistant to very corrosive chemicals and has a very high injection ratio. Has a limited shelf life. Warm temperatures and sunlight speed up breakdown. Never combine with fertilizers or other chemicals containing ammonium.
Calcium hypochlorite	Ca(OCl) ₂	No	Tablets or granules are placed in a container with water. The supernatant solution is injected into the irrigation water.		Because the HOCl form is much more effective at disinfecting than the OCl ⁻ form, the water pH should be maintained at less than 7.0	Because calcium hypochlorite is relatively insoluble, it is difficult to keep a constant concentration of free chlorine in the irrigation water throughout the day. Never combine with fertilizers or other chemicals containing ammonium.
Chlorine dioxide	ClO ₂	Yes	Dry packet placed in water, ClO ₂ solution generated overnight at neutral pH.	Plant pathogens vary in their susceptibility to the agents listed in this table, and the required concentration of oxidizing agent therefore also varies.	Injected into irrigation lines. Continuous injection of residual concentration of 0.25ppm. Twice a year shock treatment of two consecutive overnight charges of 50ppm.	Stock solution should be used within 15 days to minimize loss due to volatilization. Maximum stock concentration of 500ppm requires injection ratio of 1:10.
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.		The material being oxidized can include pathogens, peat, and fertilizer salts.	Residual effect from reaction products (peroxides, organic radicals). Breaks up biofilm. 10 grams/hr/m ₂ .
Zerotol	H ₂ O ₂ and CH ₃ COOOH	Yes	A stabilized 27% H ₂ O ₂ and peracetic/peroxyacetic acid solution that is injected directly into irrigation water. Peroxyacetic acid can be a more effective biocide than H ₂ O ₂ alone.	Because all organic matter in the water will absorb and deplete oxidizers. Good pre-filtration is essential.	27 to 540 ppm H ₂ O 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 by hand before injection.
Hydrogen Peroxide/ Hydrogen Dioxide	H ₂ O ₂	Yes	Liquid H ₂ O ₂ solutions (35% to 50% H ₂ O ₂) are injected directly into irrigation water.		25 to 500 ppm H ₂ O ₂	Not EPA-registered for water treatment in greenhouses. Requires a special injector that is resistant to very corrosive chemicals and has a very high injection ratio, or the material must be diluted by hand before injection.

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Ultraviolet (UV) radiation		N/A	Water is exposed to high doses of UV light in tubular chambers. Most common are low pressure mercury vapor lamps with a wave length of 254 nm, close to the optimum range for killing pathogens.	UV radiation disrupts the genetic material in the cell, effectively killing it. Dose, dwell time and turbidity determine effectiveness.	250 mJ/cm ² eliminates most pathogens. No residual effect on pathogens downstream of treatment.	Units capable of high flow rates commonly found in greenhouses are available. The effectiveness of the lamp decreases with age. Any particulate matter in the water will disperse the light, making the application of UV radiation less effective. Good pre-filtration is essential. Often used with other disinfecting material to get some residual effect.
Copper ionization	Cu ⁺⁺	Yes	An electrical charge is passed between copper bars, releasing copper ions into the water. A minimum conductivity (EC) of 0.3 mS/cm is needed for this process to occur.	Copper ions control algae and most pathogens, especially Pythium and Phytophthora. Recent advances in controls produce consistent copper levels and results.	0.5 to 1 ppm Cu	Not effective if water pH is above 7.0 because the copper ions precipitate. It is essential to choose a system which actively controls copper output according to flow and EC. The applied copper concentrations are a fraction of plant toxicity levels, and problems have not been reported. But until more research is done, caution is prudent.
Heat Treatment/ Pasteurization		N/A	Water is heated to specific temperature . Example: 203°F for 30 sec. Effect largely independent of water quality, turbidity.	Pathogen's resistance to heat varies. Predictable results are achieved by choosing suitable temperatures and exposure times. Effect largely independent of water quality.	An example treatment is 203°F for 30 sec. No residual effect on pathogens downstream of treatment.	High energy use makes it expensive for large flow, even as heat is recuperated to pre-heat incoming water. 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 in this publication does not imply endorsement by the authors nor OFA, 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.

Notes

- 1) Desired concentration depends on the application (e.g. shock treatment versus continuous treatment of clean water, and the specific pathogens targeted). See product label and manufacturer's instructions for your application.
- 2) All the methods mentioned above are non-specific and will 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 application, the more effective the disinfection method is at removing pathogens.
- 3) Agribrom, chlorine gas, sodium hypochlorite, calcium hypochlorite, ozone, and hydrogen peroxide are strong oxidizing agents. Metal micronutrients (copper, iron, manganese, and zinc) are easily oxidized (particularly iron). It is probable that long-term exposure (greater than 20 minutes) of metal micronutrients to these oxidizing agents will decrease their solubility. Chelated micronutrients should be only slightly less affected than sulfates.
- 4) Ultraviolet radiation is a photo-oxidizing agent. Research by Cornell University on photo-oxidation of iron in fertilizer solutions indicates that the greater the light exposure, the less iron that will remain in solution.
- 5) Quaternary ammonium compounds like Green-Shield, Physan 20, or Triathlon are listed for disinfection of walkways, benches, tools, flats, etc., but are not for use with irrigation water.