From Forest Nursery Notes, Winter 2012

298. What's in your water: sanitizing agent concentration and demand. Huang, J., Fisher, P., Meador, D., and Argo, W. Greenhouse Management 31(12):24-27. 2011.

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What's in your water?

SANITIZING AGENT CONCENTRATION AND DEMAND

Last of a four-part series on monitoring irrigation water for floriculture crops

Problems with water treatment systems designed to control algae, biofilm, or waterborne pathogens are sometimes not identified until green and slippery algae grows on greenhouse floors, emitters are clogged or plant diseases occur. That is not the best monitoring method.

Monitoring water

All water treatment systems require regular maintenance and checking. For example, copper systems rely on controlled electrolysis to form soluble copper ions, often resulting in corroded connections and plates or rods that require maintenance. If an injector is not functioning for a product such as chlorine dioxide or activated peroxygen, an incorrect level can be dosed of a sanitizing agent. Too high a dosage is a worker safety, plant phytotoxicity, and environmental risk; too little dosage leads to ineffective treatment.

On-site tests enable the grower to check the concentration of sanitizing agents. These tests, with examples in Table 1, include manual colorimetric tests, handheld meters or inline controls for continual dosage systems. Because sanitizing products are generally short-lived in water, onsite tests are the best option for reliable measurement. On-site tests have the advantage of being low cost and rapid, allowing repeat measurements and the tracking of trends over time (just as one can track water pH or EC).

Measurements of the concentration of sanitizing agents can be easily performed on site using a colorimetric test kit. These colorimetric test kits can be categorized into visual tests, such as test strips and test ampoules; titrimetric test (such as the droplet test kit where drops of a reagent is added until a color change occurs, and instruments that measure the color of solutions or test strips. Visual tests tend to be more subjective than instruments but are generally adequate for horticultural use.

We have evaluated water treatment systems in several greenhouse operations. More often than not, the technologies have either not been recently checked or the sensors are out of calibration. If the manufacturer provides or recommends a test kit, make sure the kit is used regularly – at least once a month – and has not exceeded its shelf life. Because colorimetric tests – and especially test strips – are inherently subjective, train one person to do the tests. With inline control systems, train staff to check that sensors are calibrated and ensure they have a technical and common-sense understanding of the system.

The Oxidation Reduction Potential (ORP) can be read with a meter similar to a pH meter. ORP is a measurement of the sanitizing (oxidation) power of oxidizers including chlorine, chlorine dioxide and ozone. ORP sensors are often placed in line for controlling dosage of these oxidizers, and hand held meters are also available. The units of ORP are in millivolts (mV) of oxidation or reduction and high values (650 to 800

Table 1. At a given chlorine concentration (in this case, 2 ppm), the value of oxidation-reduction potential (ORP) in chlorinated water decreases as the solution pH increases. Higher ORP values indicate higher sanitizing strength of a chlorine solution.

Active ingredients	Typical concentration ($mg.L^{-1}$)	Example Test Strips, Kits, and Meters	Web site
Activated Peroxygen and Hydrogen Dioxide	1 to 5400 $mg.L^{-1}$ H_2O_2	Test strips (such as LaMotte Insta-Test Hydrogen Peroxide Test Strips No.2984	www.lamotte.com
		Colorimetric test kits (such as CHEMets K-5510)	www.chemetrics.com
	1 to 200 $mg.L^{-1}$ PAA	Test strips (such as LaMotte Insta-Test Peracetic Acid Test Strips No.3000	www.lamotte.com
		Colorimetric test kits (such as CHEMets K-7905)	www.chemetrics.com
Chlorine, Hypochlorous acid	2 $mg.L^{-1}$ free chlorine residual	Test strips (such as Hach Free & Total Chlorine Test Strips, 0-10 mg/L No. 2745050)	www.hach.com
		Colorimeteric test kits (such as Chlorine (Free & Total) Test Kit, Model CN-66, Color Disc, 0.1-3.5 mg/L, No.223101)	www.hach.com
		Chlorine (Free & Total), Pocket Colorimeter II Test Kit no. 5870000. Free Chlorine HI 701 Checker®HC Handheld Colorimeter	www.hach.com www.hannainst.com
Chlorine Dioxide	0.25 $mg.L^{-1}$ residual	Test strips (such as LaMotte Insta-Test chlorine dioxide Test Strips No.2999LR)	www.lamotte.com
		Chlorine Dioxide, Pocket Colorimeter II Test Kit (No. 5870051), Hach chlorine dioxide reagent (No.2770900)	www.hach.com
Copper Ionization or Copper Salts	1-3 $mg.L^{-1}$	Test strips (such as Hach copper test strips No.2745125)	www.hach.com
		Model CU-6 Copper (Free & Total) Test Kit (Hach no. 2194100)	www.hach.com
		Copper, Pocket Colorimeter II Test Kit (Hach no. 5870019)	www.hach.com
Ozone	0.01 - 1 $mg.L^{-1}$ residual	Test strips (such as SenSafeTM Ozone Check test strip, No.481234)	www.sensafe.com
		Colorimetric test kits (such as Hach Model OZ-2 Ozone Test Kit, No. 2064400)	www.hach.com
		Ozone, Pocket Colorimeter II Test Kit (Hach No. 5870004)	www.hach.com
Quaternary ammonium chloride (QAC)	5 - 1040 $mg.L^{-1}$	Test strips (such as Lamotte Insta-Test Test strips No: 2951)	www.lamotte.com
		Colorimetric test kits (such as Tayor QAC test kit K-9065)	www.novatech-usa.com

mV) indicate increasing sanitizing strength. ORP is not useful for measuring concentrations of activated peroxygens (such as ZeroTol or X3) or hydrogen dioxide, or for non-oxidizing technologies such as copper or UV light.

The value of ORP in a sanitizing solution is affected by the specific sanitizing chemical, the concentration of active ingredient, and the solution pH. For example, the ORP value in a 2 ppm free chlorine solution increases as the pH decreases because the strong sanitizing and oxidizing form (hypochlorous acid) of free chlorine predominates at low pH whereas hypochlorite, a weak sanitizer, predominates at high pH. At constant pH, ORP value increases as the residual chlorine concentration increases.

One practical challenge to measuring ORP is that the water should flow over the sensor, and several minutes may be required before the ORP value stabilizes. For example, you can place a hose with solution into a bucket or other container, and place the end of the sensor into that solution. The sensor should be calibrated with a standard solution before use. Clean the sensor after each measurement, and store according to manufacturing instructions. If the water

Table 2. At a constant pH, the value of ORP in chlorinated water increases as the concentration of free chlorine increases, indicating increasing sanitizing strength.

Measurements	Analysis	Significance	Cost	Example sources	Target range
Oxidation Reduction Potential (ORP)	On site ORP meter	Sanitizing strength of chlorine, chlorine dioxide, or ozone for oxidation of microbes.	$150 to $400	Various. For example, Extech or Hanna meters. Search online, e.g. www.specmeters.com, www.grainger.com, www.pulseinstruments.net	Typical target above 700 mV.
Dissolved Oxygen (DO)	On Site DO meter	Affects ORP (high oxygen is generally desirable) and microbial growth.	$150 to $250	Various. For example, Extech or Hanna meters. Search online, e.g. www.specmeters.com, www.grainger.com, www.pulse instruments.net	5-15mg/L for agricultural crops
Chemical Oxygen Demand (COD)	Laboratory	Total oxygen required to oxidize organic materials, microbes, and some nutrients. Affects sanitizing agent demand		Water testing labs	<30 mg/L for agricultural crops
Biological Oxygen Demand (BOD)	Laboratory	Oxygen required for decomposition of organics by microbes. Affects sanitizing agent demand, and also a measure of biological water quality.		Water testing labs	BOD5 <20 mg/L for agricultural crops

TOP: Monitoring water quantity, quality and drainage is best done preventatively, rather than after problems occur. Photo by Paul Fisher
BOTTOM: Sanitizing agents can be monitored using test strips. The test strips above are used to measure (from left to right) free chlorine, chlorine dioxide, copper, peracetic acid and hydrogen peroxide. Photo by Jinsheng Huang

treatment system is injecting a sanitizing agent according to a targeted ORP value (for example, automated dosing of chlorine or ozone), then regular maintenance and calibration of the ORP sensor is an essential part of dependable control.

For plant pathogens, research has shown rapid control of Pythium zoospores with a chlorine solution when the ORP was over 700 mV. At 2 mg/L of chlorine, and pH around 7, the ORP is approximately equal to 700 mV. Research isn't yet available on the relationship of ORP and control of plant pathogens for chlorine dioxide or ozone. For control of human pathogens in wash water of fruits and vegetables, a target ORP of 650 to 700 mV is often used in packing house solutions and so is a good starting point for horticultural crops.

Sanitizing agent demand

Sanitizing agent "demand" affects how much "residual" active ingredient remains that is available to control target organisms such as plant pathogens after a chemical is dosed into irrigation water. For example, 2 mg/L (ppm) of residual "free chlorine" is recommended by plant pathologists for control of Pythium and Phytophthora zoospores. The residual free chlorine represents the combined hypochlorous acid and hypochlorite that has not reacted with organic matter or other contaminants after dosing into the water sample.

For example, a grower might find that they need to inject 5 mg/L of chlorine to pond water, in order to have 2 mg/L

of residual free chlorine at the irrigation emitter furthest away from the pond intake. In that case, the suspended solids or other contaminants would create a demand of 3 mg/L (5 mg/L applied minus 2 mg/L residual). That means that 5 mg/L of total chlorine would need to be applied at the source to have the 2 mg/L of residual free chlorine available for control of pathogens present in the irrigation system at the furthest outlet.

Demand will usually change during the year and can even change during a crop production cycle. For example, the density of microbes tends to increase in pond water as the temperatures increase in the summer. Increased demand will reduce the residual free chlorine. Consequently, the residual concentration of free chlorine may be too high in the winter (causing phytotoxicity and wasted chemical), or too low in the summer to control the target pathogens. This change over time means that regular testing of dosed and residual active ingredient is advised. The same concept can be applied to sanitizing agents other than chlorine.

Sanitizing agents can be measured using colorimetric test kits combined with a pocket colorimeter. A reagent is added into the solution, and a digital meter interprets the color change as a concentration. The HI 701 Checker HC Handheld Colorimeter (left) measures free chlorine, and the Thermo Scientific Orion AQUAfast AQ4000 Colorimeter (right) can be programmed to measure virtually all the sanitizing agents. Photos by Jinsheng Huang and Dustin Meador

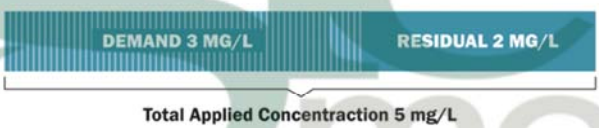

Figure 3 The residual concentration of a sanitizing agent (in this case, 2 ppm) that is available to control pathogens equals the total applied concentration (5 ppm) at the injector minus the demand (3 ppm) from contaminants in the irrigation water.

Other ways to measure the demand of a water sample is the biological oxygen demand (BOD, Table 2) and chemical oxygen demand (COD). These variables are mainly used in drinking water supplies, although the EPA has recommended levels for irrigation use. The BOD represents the amount of oxygen used up by microorganisms to decompose organic waste matter in water. To measure BOD, the dissolved oxygen is measured in the water, the container is closed and incubated at a constant temperature for a set period (for example, five days), and then dissolved oxygen is again measured. The measured drop in oxygen is the BOD. The COD is similar, but tests how much of a strong oxidizing chemical is needed to completely oxidize the contaminants (particles, ions, and microbes). Although BOD and COD are related to the amount of sanitizing agent required in horticulture irrigation water, this relationship is not direct and requires further research.

Dissolved oxygen (DO) levels are important for root health in hydroponic production. Researchers have found that when root zone oxygen level dropped to below 3 ppm in hydroponics, tomato plant roots were much more susceptible to *Pythium* infection, and growth of tomato and cucumber was reduced. Aeration of pond water reduces algal growth, and 5 mg/L is recommended to avoid fish kills. Aerating subirrigation tanks is likely to increase efficacy of oxidizers such as chlorine, however clear recommendations are not yet available. **GM**

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The authors thank sponsors of the Water Education Alliance for Horticulture (watereducationalliance.org) for supporting this series, including AquaPulse Systems, BioSafe Systems, Blackmore Co., Chem Fresh, Chlorinators Incorporated, DRAMMwater, Fafard, Greencare Fertilizers, Griffin Greenhouse and Nursery Supplies, Hanna Instruments, Phyton Corporation, Pindstrup, Premier Horticulture, Pulse Instruments, Quality Analytical Laboratories, Sun Gro Horticulture and Trueleaf Technologies. The authors also thank the USDA-ARS Floriculture and Nursery Research Initiative and the Young Plant Research Center (floriculturealliance.org) for supporting the underlying research.