Recycled water quality dynamics and implications for ornamental crop production©

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INTRODUCTION

Capture and reuse of agricultural runoff for irrigation was first adopted primarily for environmental protection (Skimina, 1986). Over the past 30 years, this practice has evolved to be an important sustainability strategy for many ornamental crop production nurseries. However, until very recently, little was known about recycled water quality dynamics in runoff containment ponds (Hong et al., 2009). In that 2009 study, we discovered through continuously monitoring that water quality in a containment pond fluctuates dramatically over time with pH being mostly alkaline. To determine whether this fluctuation and alkaline pH prevalence also occur in other containment ponds, we have since expanded the monitoring program to include nine ponds in Virginia, two in Maryland, and one in Mississippi through a joint project with University of Maryland and USDA ARS Southern Horticultural Lab (http://www.irrigation-pathogens.ppws.vt.edu/). This expanded monitoring demonstrated that dramatic fluctuation and alkaline pH prevalence are common in containment ponds (Zhang et al., 2015a, b, 2016). This presentation uses a small subset of the Virginia data to illustrate this and some other major findings and discuss their potential implications for ornamental crop production.

CONTINUOUS MONITORING OF WATER QUALITY

Water quality monitoring was performed in eight recycling irrigation ponds and one adjacent small stream at three nurseries in eastern Virginia (VA1 and VA3) and central Virginia (VA2). At nursery VA1, the first pond, labeled VA11, receives storm water and irrigation runoff directly from ornamental crop production areas. Water flows from VA11 to VA12 through a culvert. When VA12 is full, water can flow into VA13 by opening a sealed culvert. Both VA12 and VA13 are pumped for irrigation. VA10 is a small stream that flows along the perimeter of the nursery and does not receive any runoff water from the nursery production areas. At nursery VA2, three ponds (VA21, VA22 and VA23) have a similar arrangement of water flow. However, VA21 has a large holding capacity thus water in this pond seldom overflows into VA22 unless there is a severe storm with heavy rain. VA23 receives water from VA22 through a connecting culvert and is the only pond used for irrigation. VA31 and VA3X at nursery VA3 are not connected. VA3X receives some runoff water from nearby agronomic crop fields outside of the property, while VA31 directly receives irrigation and precipitation runoff from production areas at this horticultural facility.

A multiprobe Sonde (Figure 1) was anchored in the middle of each selected pond and set to continuously record surface water quality. Water quality parameters monitored included temperature, pH, oxidation-reduction potential (ORP), electrical conductivity (EC), turbidity, dissolved oxygen (DO), chlorophyll *a*, and blue-green algae, plus the depth at which water quality data were taken. Recorded data were communicated directly from four Sondes in VA10, VA12, VA 21, and VA23, respectively, to an office computer via telemetry systems and Verizon satellites or manually downloaded from other Sondes. Sondes set for real-time data communication were programmed to record data every 15 min., while the others recorded data hourly.

As shown in the computer screenshot (Figure 2), the system was programmed to have a background photo showing a pond where water quality was being monitored and different gauges showing real-time water quality data in the pond with pH, DO, EC and depth on the

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top, while chlorophyll *a*, blue-green algae, turbidity, temperature, and ORP at the bottom. The gauge in the middle was a system status gauge; a green check indicates that the system works properly, while a red cross would mean that the system is out of service.

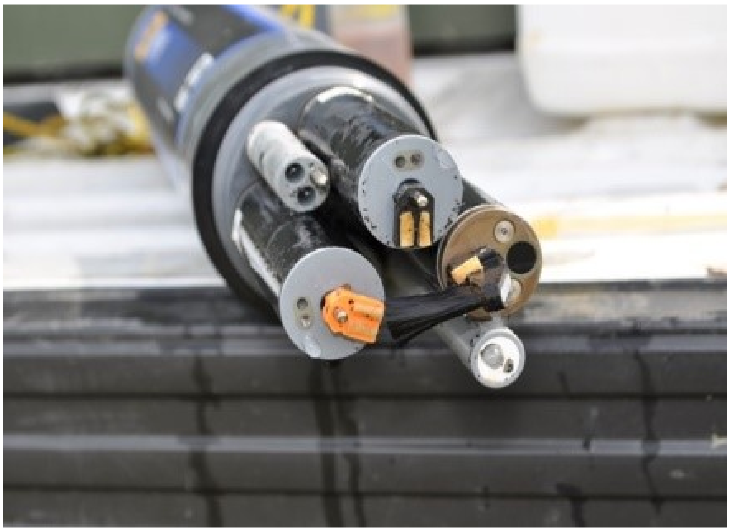

Figure 1. A multiprobe Sonde set to continuously monitor water quality.

Figure 2. Real-time data communication via a telemetry system and Verizon satellites.

RECYCLED WATER QUALITY DYNAMICS

Water quality fluctuation and alkaline pH prevalence are common in recycling irrigation ponds

As illustrated with water pH and DO in three ponds and one adjacent stream over a 5-week period from April to May 2011 (Figure 3), recycled water quality fluctuated dramatically over time. The degree of fluctuation was proportional to the load of nutrients that nurture algal bloom and cycling. The more nutrient load, the greater degree of fluctuation! For example, water pH in VA12 receiving runoff water overflowing from a small sedimentation pond fluctuated from 6.4 to 9.5 during this short period of time. In contrast, water pH in VA10 receiving no runoff water from production areas had little fluctuation with readings consistently at slightly below 6.0. Likewise, much greater degree of water pH fluctuation was observed in VA21 than VA23. Similar patterns and differences were also seen in DO between two pairs of ponds/stream. These new data support our previous finding (Hong et al., 2009) and demonstrate that water quality fluctuation and alkaline pH prevalence are common in containment ponds.

Recycled water quality also may fluctuate greatly within a day

There also were diurnal patterns of water pH and DO fluctuation in these ponds/stream, bottoming around 6 A.M. and peaking between 4 and 5 P.M. (Figure 3). As with their seasonal patterns, these diurnal patterns were closely related to photosynthesis activities in ponds. When the sun rises, algae and other photosynthetically active agents remove carbon dioxide, a weak acid, from water to make carbohydrate while releasing oxygen. Consequently, water pH and DO goes up. This process is expedited as temperature rises. Thus, recycled water pH, DO and temperature fluctuate almost simultaneously. These diurnal fluctuations depended upon the nursery location, nutrient load, and the time of year. The greatest pH difference from the lowest to the highest point of day across all ponds monitored was 3.5 units.

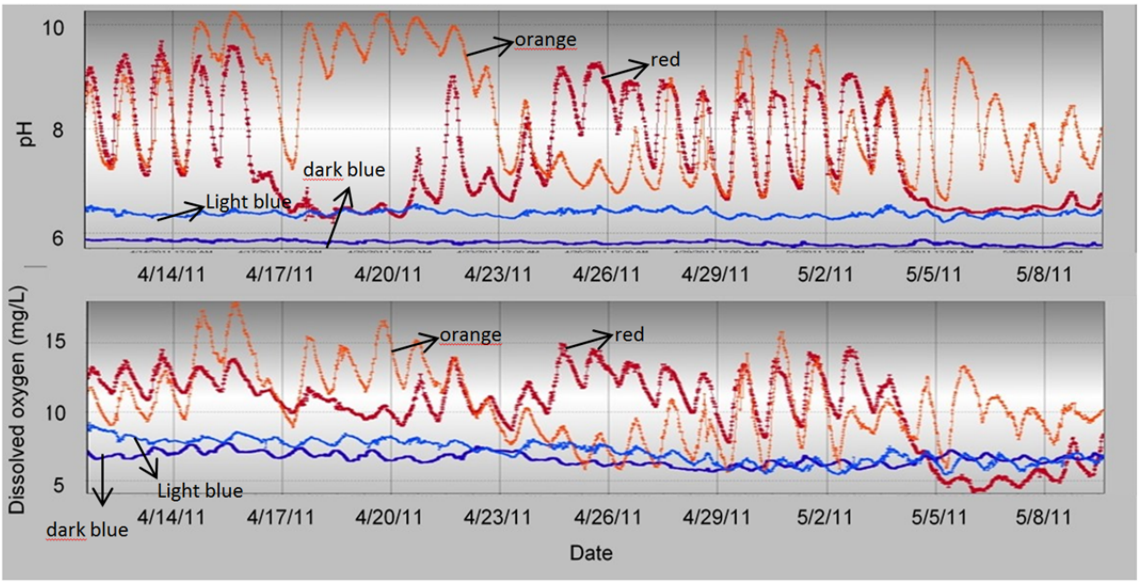

Figure 3. Seasonal and diurnal fluctuation of water pH and dissolved oxygen in VA10 (dark blue), VA12 (red), VA21 (orange) and VA23 (light blue).

Recycled water quality varies at different depths of water column

Recycling irrigation ponds generally are shallow. The depth of water column across all ponds and stream we monitored ranged from 0.8 to 3.9 m (Zhang et al., 2016). It was found by surprise that water column was thermally stratified from April to October in all the ponds including the shallowest sedimentation pond, with the warmer and lighter water on the surface layer (epilimnion), cooler and heavier water in the bottom (hypolimnion), and a transition zone in the middle (Metalimnion) (Zhang et al., 2016). This thermal stratification prevents water mixing within water column, pushing surface water quality fluctuation to the extremity (Zhang et al., 2015a). As a result, water pH is normally 1 or 2 units higher at surface than at depth of water column.

IMPLICATIONS FOR ORNAMENTAL CROP PRODUCTION

As we have just begun a steep learning curve on recycled water quality dynamics, our knowledge about its impacts on ornamental crop production is largely not known at this time. Here we will use water pH as an example to discuss how it may affect crop growth and quality, nutrient availability, and the performance of chlorination, a water treatment technology that is widely used in the ornamental horticulture industry.

Growth and flower quality of some ornamental crops

Per the general irrigation water quality guidelines (Yaeger et al., 1997), recommended pH range for ornamental crop production is 6.5 to 7.0. Once pH goes above 7.0, the degree of problem increases. A recent study with peony (*Paeonia lactiflora* Pall.) has clearly shown that irrigation water pH negatively impacted plant growth and quality in a number of ways (Zhao et al., 2013) For example, plants irrigated with water at pH 7.0 produced the largest and most colorful flowers, while those irrigated with water at pH 10.0 did not have flower at all. Similar water pH impacts were observed in another study with marigold (*Tagetes* spp.) Plants irrigated with water at pH 7.8 produced fewer flowers and had a lot more yellowing lower leaves than those irrigated with water at pH 6.4 (Valdez-Aguilar et al., 2009). Recycled water pH is mostly alkaline (Hong et al., 2009). How this range of water pH may impact the growth and quality of other ornamental plants is yet to be determined.

Nutrient availability

Nutrient availability is subjected to pH (Yaeger et al., 1997). Among the micronutrients most prone to prevalent alkaline pH are iron, manganese, copper, and zinc. If recycled water is used for irrigation, these elements should be the first to be checked when potential nutrient deficiency issues emerge. Many nurseries now use Actino-Iron® as a fungicide and in some cases also as plant growth enhancer. Whether there is a linkage between increased use of recycled water for irrigation and the benefits of applying Actino-Iron® at production facilities is a worthwhile question for horticulturists to look into in the future.

Chlorine performance

Chlorination remains the most cost-effective water treatment today but its performance is really subject to water pH due to its chemistry (Hong and Richardson, 2004; Hong et al., 2003). There are two major species of free chlorine in water: hypochlorous acid (HOCl), a strong sanitizer, and hypochlorite (OCl), a weak sanitizer. Hypochlorous acid is estimated to be 20 to 80 times more effective than hypochlorite in controlling *Escherichia coli* (White, 2010). These two free chlorine species are in equilibrium in water, depending upon pH (Figure 4). At pH 5.0 to 5.5, all free chlorine is hypochlorous acid. This is the pH range at which chlorine is most efficacious. As water pH increases, hypochlorous acid portion of the free chlorine drops rapidly while hypochlorite portion increases equally. As a result, chlorine performance decreases sharply, by 25% at pH 7.0, 74% at pH 8.0, and 90% at pH 9.0. As the most likely pH range for recycled water is 8.0 to 9.0 or even higher, so treating such water without prior-acidification, a large percentage of chlorine dollars would be lost.

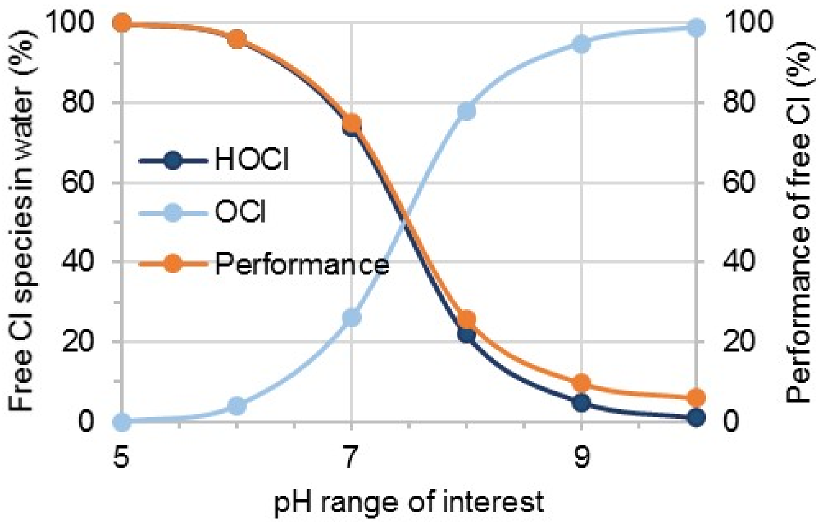

Figure 4. Water pH and chlorine performance (Assuming that OCl efficacy is 1/20 of that of HOCl).

RECOMMENDATIONS

Based on what we have learned so far about recycled water quality and its potential impacts, taking a few simple steps outlined below will help improve crop quality and productivity and stretch your investment dollars.

1) A multi-pond recycling system is ideal if you can afford it. The system should have a stepwise water flow with runoff from all production areas being captured in the top pond. Water should be pumped out from the bottom pond for irrigation use, as did nursery VA2.
2) Place the pump inlet in the middle or slightly below in the water column because its water pH could be a couple units lower than that of surface water and such a pH decrease will chlorine performance and other benefits.
3) If your chlorination system turns on automatically when irrigation is cut on, irrigate crops in the morning when water pH at its lowest point of the day. This will also improve the performance of your chlorine dollars.

Not every grower has the luxury to implement all three recommendations above. But recommendations #2 and #3 could be easily implemented at every and each nursery - requiring no or little additional investment. These two recommendations alone should greatly mitigate the negative impacts of recycled water quality on crops while stretching the chlorine dollars. In cases where recommendations #2 and #3 are not sufficient—the next step is to check water pH regularly, and adjust as needed for the optimum chlorine performance, crop quality and productivity.

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