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Selectrocide™ Chlorine Dioxide as a New Product for the Control of Algae and Other Microbial Pests in Greenhouse Irrigation Systems©

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THE ALGAE PROBLEM

Algae cause a number of problems relating to greenhouse management. It forms on sidewalls of the greenhouse, particularly when plants are grown close enough for fertilizer solution to splash, drip, or drain onto the glazing material (Fig. 1). The advanced stage of development reduces light transmission through the sidewall and growth of plants in the immediate vicinity. It is viewed by many as a nuisance and can lead customers to form a negative impression of the operation by suggesting that cleanliness and good sanitation practices are not priorities.

Its presence is known to provide feeding and breeding areas for insects such as fungus gnats and shore flies (Fig. 2). Populations of these insects are known to vector plant diseases, particularly those that occur in the growing medium. A shore fly population, if present in a retail area, can be quite distracting and cause shoppers to question whether the "bugs" are going to harm the plants they purchase. Until recently we responded by saying shore flies were only nuisance pests and would not harm plants. Research has shown otherwise, and shore flies are now known to spread diseases in the same way that fungus gnats do.

Algae cause direct crop loss when present on the growing medium surface of seedling plugs (Fig. 3). Young, tender seedlings are negatively affected as advanced algae development results in loss of crop uniformity and forces compromised growing decisions. If the larger seedlings are dry yet the smaller seedlings are not, should the plug tray be watered? If a chemical growth regulator application is scheduled, when should the tray be treated? Regardless of the decisions, some plants will either be over-watered or under-watered and receive too much plant growth regulator or not enough. At some point, the additional expense of hand labor becomes necessary to grade the plants prior to use.

Advanced stages of algae develop mats that repel water, making it difficult to keep the growing medium moist. As the mat matures, it creates a slimy surface that presents further impediments to seedling growth. This thick layer can attack the base of the stem of tender seedlings causing collapse and death.

Dark green to black patches of algae on floors and walkways, in addition to providing breeding areas for insects and diseases, can become slippery and cause safety concerns for employees and customers.

Algae can clog drip emitters (Fig. 4), mist nozzles and water breakers, solenoid valves, and other parts of irrigation systems. Discussions with growers repeatedly touch on the following cost associated with algae. Clogged drip tubes, particularly those used for hanging baskets, cause significant concern and crop loss. Not only do drip emitters need to be replaced after failing, but more often than not, the

Figure 1. Algae forming on greenhouse sidewalls.

Figure 2. Algae provides feeding and breeding areas for insects.

Figure 3. Algae on growing medium surface causes crop problems.

Figure 4. Algae and biofilm cause clogging of drip emitters. New emitter on left, clogged on right.

Figure 5. Schedule 80 PVC will not prevent algae growth inside irrigation lines.

clogged emitter is only identified after the hanging basket is damaged or killed from lack of water.

Several growers have reported to me that they replace thousands of drip emitters after every spring production season. Stories are also told of growers who remove the filter cartridges from their in-line filters because they become clogged too often. Think about that!

Understanding the Enemy. I have heard the following advice regularly in conversations about irrigation systems. Don't use Schedule 40 PVC in the greenhouse because its white construction allows sunlight to penetrate, which allows algae to grow inside the pipe. Use schedule 80 PVC instead (Fig. 5), because it's thicker, gray construction prevents sunlight penetration, which prevents algae from growing. For growers who have followed this advice; Schedule 80 PVC pipe and fittings cost between two to three times as much as schedule 40. Other growers have told me that they used to paint their irrigation lines black for a similar reason. While the logic seems sound, read on to learn why adopting either of these practices amounts to nothing more than throwing money and time down the drain.

Two years ago I was in a 5-ft deep ditch (Fig. 6) cutting into 2-inch water and fertilizer mains to service a new greenhouse. Upon cutting through the fertilizer line I was left scratching my head in bewilderment. That fertilizer main was lined with the greenest layer of algae imaginable, 5-ft underground in complete darkness.

I had been under the impression for many years that algae require light to survive. How could I have algae 5-ft underground? I next cut through the clear water

Figure 6. Underground clear water and fertilizer mains, which were cut to show algae and biofilm growth in the absence of sunlight.

Figure 7. Longitudinally cut PVC mains; top section is new, middles section carries clear water, bottom section carries fertilizer. Note discolored biofilm layer in clear section and algae dominated layer in bottom section.

Figure 8. Experimental irrigation matrix for researching biofilm and algae in irrigation lines.

line and, while it was not lined with green algae, it was lined with a distinctive brown deposit. I saved samples of each pipe and cut them longitudinally to document my finding in a picture. In Fig. 7, the top section of pipe is new, the middle section is the clear water line, and the bottom section is the fertilizer line.

A NEW WORD: BIOFILM

The research team I am working with on the chlorine dioxide project includes both chemical and physical engineers and a microbiologist. It was the microbiologist who raised my knowledge of algae to a new level. The brown lining inside my clear water line is a network of living organisms called biofilm (also called bioslime, slime). Biofilm is a complex of bacteria and both organic and inorganic components that form a persistent, living layer inside irrigation lines. The continual flow of water through the pipe replenishes nutrients, which allows the biofilm layer to sustain itself. When fertilizer is injected into this environment the biofilm flourishes and is able to form a symbiotic relationship with algae. What one needs the other provides. The result: biofilm becomes capable of replacing algae's need for sunlight.

This is why the schedule 80 recommendation and painting irrigation lines are doomed to fail.

The Research. An experimental irrigation system was designed to allow us to research a new product, Selectrocide™ brand chlorine dioxide. The accompanying pictures on the right show the manifold system (Fig. 8). Four independent zones each included a dedicated Dosatron injector. A fifth zone was installed without an injector to serve as a control. Sections of clear PVC pipe in each zone allowed us to see algae as it grew in the pipes. It also allowed us to take pictures of how well various treatments killed the algae lining the pipes.

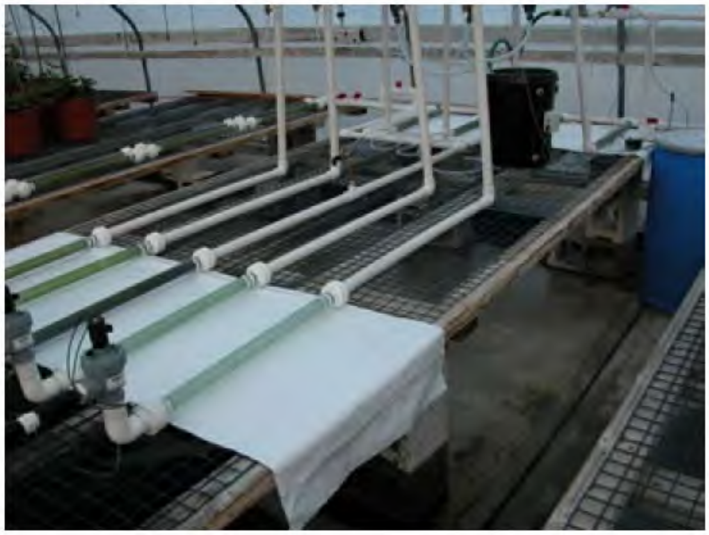

Figure 9. Clear sections of PVC installed to view algae and biofilm development.

Clear sections of pipe were also installed before the injectors to confirm that the lines were contaminated with algae during the time that the various chlorine dioxide treatments were occurring. These sections are visible in Figure 9. Our strategy was simple: if the water before the injector was green and the water after the injector was clean...we had a winning treatment. A common, constant fertilizer solution of 200 ppm nitrogen was used during the experiments.

Shock Treatment. Within weeks after installation a dark green layer of algae formed inside the clear sections of the manifold (Fig. 9). The first series of experiments was designed to determine how a contaminated irrigation line could be shocked to kill and strip algae and slime from the line.

Figure 10A shows our first results. The clear section of pipe in the foreground received an overnight shock treatment of 50 ppm chlorine dioxide. The pipe was filled or "charged" at the end of the day and left that way overnight. The line was flushed the following morning prior to taking the picture. The green pipes in the upper portion of Fig. 10B were not treated. The treated pipe was just as green as these before the chlorine dioxide shock treatment was made. Needless to say, we were quite pleased with the results.

In the next step we repeated the overnight shock treatment to determine if additional shock treatments would be beneficial. Figure 10B shows one such experiment where different concentrations and number of overnight exposures were studied. The untreated control line is the dark green line in the center. Two consecutive, overnight shock treatments of 50 ppm provided excellent removal of algae and slime inside the lines. Shocking for more than two nights did not provide additional benefit.

A

B

Figure 10A & 10B. Top image showing clear section of line following shock treatment with Selectrocide. Bottom image showing various treatments with untreated control line in center. Note algae contamination in center line.

Our recommendation will call for one's entire irrigation system to be shocked for two consecutive nights, twice a year. The timing of these two shock treatments could be in January and July, between major crop cycles.

Continuous Treatment. Shocking the experimental system gave us 4 to 6 weeks of residual effect before we noticed visible signs of algae reforming in the clear sections of pipe. The next step was to investigate how an ultra low concentration of chlorine dioxide, injected continuously into the irrigation system, would prevent algae and other microbial organisms from establishing their presence.

Figure 11 shows results of an experiment, which began with two consecutive overnight shocks of 50 ppm to ensure that all lines, including the center control line, were clean. Following the shock treatments ultra-low, continuous injection of chlorine dioxide started. Concentrations included, from top to bottom: 0. 1, 0.25, control, 1.0, and 2.0 ppm, respectively. The picture was taken 12 weeks into treatment. Notice that the control line became dark green with re-established algae. Note also that the lowest concentration of 0.1 ppm (top line), while not nearly as green as the control, shows visible signs of the return of algae. Concentrations of 0.25 and higher all prevented re-establishment of algae. Based on these and other results, our recommended continuous concentration will be as little as 0.25 ppm following periodic shock treatments to keep the irrigation system and water algae free.

FROM RESEARCH TO THE COMMERCIAL GREENHOUSE

One of the most enjoyable and valuable aspects of my research is being able to take scientific results and apply them in my commercial greenhouse before making

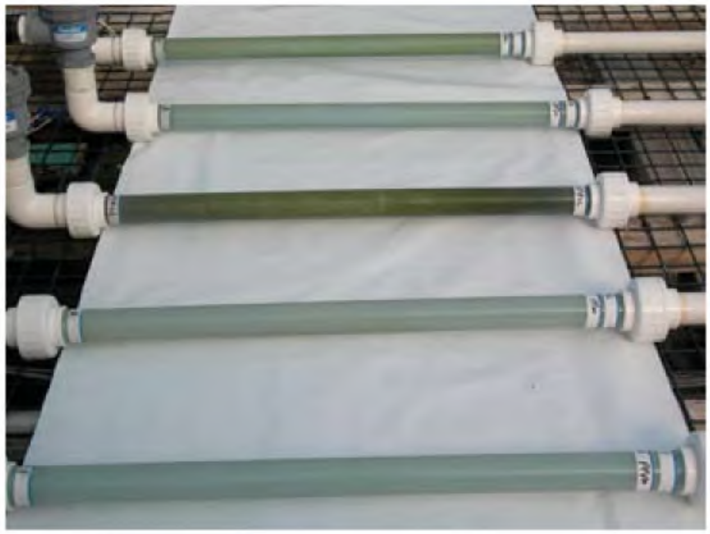

Figure 11. Clear sections of lines following continuous injection of Selectrocide with untreated control in center.

general recommendations to fellow growers. I love this part of the process. My early research with Florel generated results that were so encouraging I actually considered questioning their accuracy. As soon as I saw the same results on my commercial crops I knew I had something significant to report.

The chlorine dioxide research that we've conducted to date is following the same path as Florel. The research manifold results presented above were so dramatic that we repeated them to make sure what we were seeing was real. Then, we developed a commercial recommendation that we tested on the rest of my greenhouse range.

With the cooperation of Hal Blakeslee from Anderson injectors and both Lela and Eddy Kelly from Dosatron International, we have developed a protocol that will allow growers with either type of injection equipment to perform both the shock and continuous treatments to obtain terrific results in traditional, nonrecirculating irrigation systems.

Anderson provided a 50-gpm unit to the project that I installed at the closest point to where municipal water enters my range. The injector was installed after the town water meter and an updated backflow preventor. I installed one access valve before the injector to be able to sample water off the street before treatment. It's the only valve on my range from which untreated water can be drawn.

The new Anderson unit began operation on 21 Jan. 2005. Half of my range was open and heated at that time, and the irrigation lines in these houses were given two overnight shock treatments at 50 ppm. On 23 Jan. I began injecting the continuous dose to treat every drop of water entering my range.

The Recommendation. Summarizing, the recommendation for using Selectrocide™ chlorine dioxide to prevent algae, slime, and other microbial growth from contaminating traditional nonrecirculating greenhouse irrigation systems is:

- Twice a year shock treatment consisting of two consecutive overnight charges of 50 ppm.
- Continuous injection to maintain residual level of 0.25 ppm for remainder of year.

Details of Injection. The EPA label for Selectrocide™ chlorine dioxide is based on a stock solution concentration of 500 ppm. Based on this concentration, in order to deliver the shock treatment an injection ratio of 1:10 is required. This will inject one part of 500 ppm stock solution into nine parts of water to achieve a diluted concentration of 50 ppm.

Once the shock treatment was mastered, the continuous dose was considerably easier to deliver. Our target concentration was 0.25 ppm. We began injecting this concentration on 23 Jan and immediately found that none of it was making it out the end of the hoses further downstream in the system. We realized that the 0.25 ppm of chlorine dioxide was being consumed by something in my water. The concentration was gradually increased until we could detect 0.25 ppm coming out of the hoses and mist nozzles. We settled on injecting 0.5 ppm to achieve the desired 0.25 ppm residual level downstream. At the time of writing, this injection strategy was into its 3rd month and working beautifully. To achieve the continuous injection of 0.5 ppm the stock concentration was lowered to 300 ppm. This allowed the injector to run within its usual range of injection ratios.

What About My Water? A major turning point in this project occurred when the microbiologist, upon sampling my town water as it entered my range, documented algae in the supply repeatedly. Learning that I have been paying to receive algae in my water all these years has been an eye-opening experience.

Immediately after learning this fact my treatment strategy changed. I saw no alternative but to do what was necessary to treat the water as soon as it reached my side of the meter. Before this realization, our strategy was to inject chlorine dioxide through my central fertilizer injector. The reason? The injector was already in place. The problem? Injecting at this point only treated half of my irrigation system. My range is designed with independent clear water and fertilizer lines in every house.

It makes sense that, once we documented algae in my water, the continuous injection needed to be high enough to kill the algae and still end up at the residual level of 0.25 ppm. I have been injecting 0.5 ppm continuously ever since. Occasional minor adjustments to the Anderson injection ratio have allowed me to maintain the desired target range using a stock solution concentration of 300 ppm.

Another aspect of the logic to treating every drop of water at its source is that, if the water is free of algae, then injecting fertilizer further downstream doesn't create the problem it once did. Without algae in the first place, the nutrients can't add fuel to a fire.

Continuous Treatment...Wow! A week after we began the continuous injection we began sampling my water to document the effects of this injection strategy into the entire irrigation system. Samples were taken immediately before the injector (untreated water from street), immediately after the injector, and directly from mist nozzles in my propagation house several hundred feet downstream. Sampling continued throughout the spring production season from January to June.

Water samples are taken directly to a laboratory for analysis. After culturing the water samples on agar in Petri dishes, colonies of bacteria, algae, and fungi are seen as small spots. One criterion used in water testing is the number of colonies per unit of water. The higher the microbial count, the higher the level of contamination of the sample. A second step in the analysis is sampling, culturing, and identifying the individual colonies.

Samples were taken several days after continuous injection of Selectrocide™ chlorine dioxide in January. The three samples were untreated water immediately before the injector (municipal), treated water immediately after the injector, and treated water from propagation house mist nozzles further downstream. The results have been stunning. A high concentration of microbial colonies, some of which were identified as algae, was found throughout the sample labeled "municipal." However, colony free samples resulted from the "post injection" samples immediately after the injector and "propagation house clear water" representing the sample from the mist nozzles.

A picture and a Thousand Words. The treatment recommendation that we have developed is sound, and it works. The lab samples pictured above speak volumes...even water from highly treated municipal supplies contain levels of algae that can cause problems in our greenhouses. Pond, stream, and well water have all been shown to have the capability to contain algae.

I'm hoping that these research results and the knowledge we've acquired to date help convince growers who are having problems with algae and other, nonvisible microbial contamination that treatment as close to the water source as possible is the best strategy for achieving success. If our irrigation systems can be treated and maintained algae free, there will be one less avenue for this problem organism to enter the greenhouse. Keep reading, we haven't finished the story yet.

Anywhere Else that Algae Comes From? There is another piece of the algae puzzle we've been able to put into place during this project. Our microbiologist, after learning how crops are grown in a commercial greenhouse, told me that algae are capable of living in acidic peat bogs where our peat is harvested. During processing the peat is dried, which triggers the algae to go dormant. Once in a warm, moist, and fertilized container in the greenhouse the algae become active again and able to grow. In this environment, light is required and the accompanying pictures of draceana spikes below tell a familiar tale.

The curling mat of algae on this long-term crop speaks loudly about its water-repelling characteristic (Fig. 12). When developed sufficiently, it can be peeled off the growing surface in one piece. Notice also, just below the algae mat, that the growing mix is clean and fresh. In this environment, no sun...no algae.

Commercial Growing Media. Back in January we sampled several growing mixes and components that I had in my warehouse. We still blend our own growing mix using some topsoil, peat, coir, and rock wool and steam pasteurize it before use.

The picture to the right shows three cultures, clockwise from top: my freshly steamed mix, a commercial plug mix, and the raw peat/coir component used in my mix. Some of the microbial colonies in the plates represent beneficial nitrifying bacteria.

Figure 12. Crusted, water repelling algae mat on growing medium surface.

Unlike the goal of irrigation water, we do not want a microbe-free environment in the growing mix. With that said, we identified algae in all three samples. Wow! We are currently sampling from a larger number of commercial mixes to document the widespread presence of algae. Some of these mixes are being used in simulated growing conditions to determine if surface algae can be grown using sterile water. If we show this to be the case, it will add to our knowledge base and help identify another point of entry for algae in the greenhouse.

Before ending this issue, take a look at the two drip emitters pictured in Fig. 4. On the right is an emitter I removed from a hanging basket drip line after finding it had failed. Note the accumulation of biofilm at the tip, which has plugged the emitter. We analyzed the plug and have confirmed that it is not particulate matter that passed through my filter but, rather, biofilm and algae that have become established inside the line. On the left is a new emitter for comparison.

For now, I'll leave you with the following message regarding this exciting research. **To Be Continued...**