GROWERTALKS

Features

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You’ve Got Biofilm

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As a grower, you know that your plants need high-quality water to thrive. What does high-quality water look like and how do you get it? The highest quality irrigation water meets three critical criteria:

- It presents no threat from water-borne pathogens
- It doesn’t damage the roots or stress the plant
- It enhances the health of the plants

To address that first factor, we have to focus on the most significant aspect of water-borne pathogen control—biofilm.

What’s biofilm?

Biofilm is defined as a self-sustaining layer of microorganisms aggregated in an extracellular matrix on surfaces exposed to liquids and protected from being killed by most types of antimicrobial agents. In other words, it’s a film growing in pipes, tanks every other surface of your irrigation system.

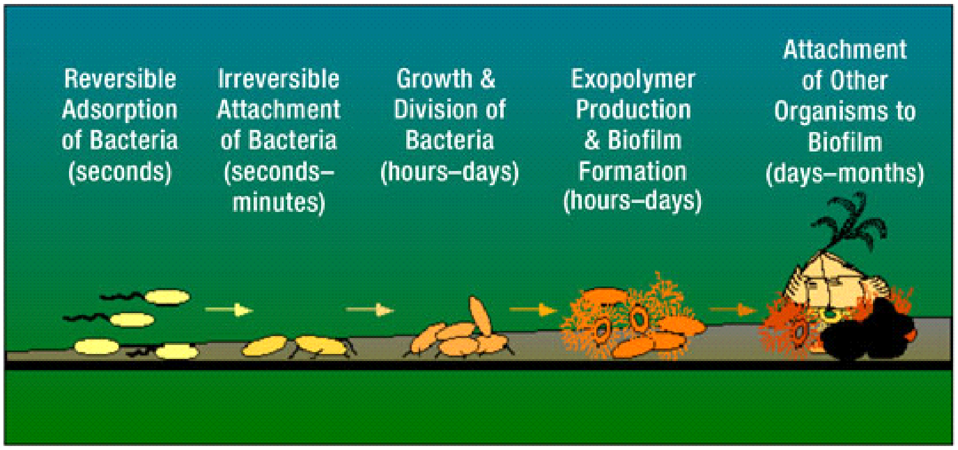
There are two primary components of every biofilm: 1) the “matrix” that adheres to the walls of any wet surface and forms a micro-colony of support; and 2) the planktonic/free floating cells that attach to, feed from and develop on this matrix and then break off to form new biofilm colonies and are also dispensed on the outlet of the pipe … onto your plants.

There are three critical things to know about biofilms:

> 1. Biofilms exist in every irrigation system. No exceptions.
> 2. Mature biofilms form in minutes and hours, not days and years.
> 3. Biofilms are likely the largest source of water-borne plant pathogens.

Unfortunately, it’s not as easy as we used to think to eliminate or even substantially reduce water-borne pathogens. It’s been commonly thought of as a one-step process: disinfection of the source water. But it turns out that removing biofilm is the most important factor. Several research results suggest that two-thirds or more of the water-borne pathogen threat to your plants is coming from the biofilm in irrigation systems, even with a clean water source.

Two common beliefs are that, since municipal water is already treated, and that well water is (usually) naturally free of pathogens, then plants irrigated from those sources will be free of the threat from water-borne pathogens. Neither assumption is true, in part because it's possible, and with municipal water even likely, that pathogens do exist in those sources. It's also commonly believed that if irrigation water from a pond or other surface water source is disinfected before it gets to your irrigation system or plants, this will eliminate the threat from water-borne pathogens. Also not true.



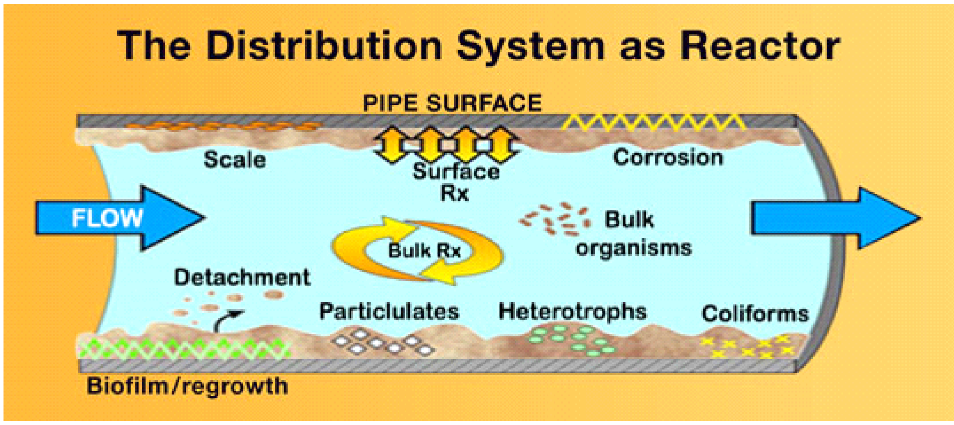
Above: The five stages and elapsed time of biofilm development.

To be fair, these assumptions were, at one time, reasonable: we simply didn't know any better until about a decade ago. Until then, there was little evidence that water-borne pathogens came from anywhere other than water sources, so it was logically assumed that if you kill the pathogens in the source water, it was safe. Consultants, academia, extension services and the purveyors of water-treatment systems supported that idea by recommending solutions that mostly addressed only disinfection of the source water. Disinfection solutions such as UV light, heat pasteurization, chlorine and other products and methods have been, and still are by some, promoted as adequate in and of themselves. And, to be fair, if properly employed, these methods are all able to kill or reduce pathogens to appropriate levels. So what's not to like? Clean is clean, right?

Think about it this way: You wouldn't wash fresh lettuce and then serve it on a dirty plate. Or pour fresh water into a glass with yesterday's milk scum in it. Yet when we take clean water from a source and put it into an irrigation system without a continuous process to eradicate biofilm, we're doing the same thing. The clean water, treated or not, becomes re-populated with the same pathogens that we may have just removed from it.

Science has long known about the existence of biofilms, going all the way back to 1684 when a Dutchman wanted to know why his teeth were yellow. We've long known that biofilms are found in humans, animals, pipes, tanks and any surface that's exposed to moisture. But many of the more onerous characteristics of biofilm have only been discovered relatively recently, starting in about 1990 with the founding of the Center for Biofilm Engineering at Montana State University. Thanks to that original research, and programs since at other universities, we now understand that biofilm is far more ubiquitous, grows much faster, causes more diseases and is far more difficult to eliminate than was previously understood.

Below: How biofilm clogs in drip emitters.



Where does biofilm come from?

There are millions of bacterial cells in one milliliter of "clean" water. No different than what we all know about the human body. Even when we're healthy, our bodies contain billions of both good and bad bacteria. We have a complex immune system that, when it's functioning correctly, controls the number of good versus bad microorganisms, so we stay healthy. We just need to provide proper care and feeding to our system for it to work well.

In an irrigation system, there's no immune system to manage the good and bad microorganisms. It's just PVC pipe, after all. So proper "care and feeding" of the system is the only way to keep our irrigation systems in proper balance before the water gets to the plants. Done properly, we can feed the plants water that further enables and enhances their immune system. (More on that later.)

The moment clean, fresh water enters a perfectly clean pipe, a few of those millions of microorganisms find a way to latch onto the pipe surface for a moment, even on the smoothest surface (stage 1 biofilm). This happens within a few seconds of turning on the clean water into a clean pipe. Once these microorganisms are latched on, they begin to secrete a substance that fixes them to that surface (stage 2 biofilm). After a few of their buddies arrive, they form a community that pulls oxygen and nutrients (which you supply via fertilizer) from the passing water. The community thrives and grows. This is what's referred to as the "biofilm matrix" (stage 3 biofilm).

It's important to know that the growth of the biofilm develops nearly as quickly upstream against the flow as it does downstream with the flow. And all of this takes place within a few hours to a few days of that clean water flowing into a clean pipe.

One of the interesting characteristics of this matrix that makes it very tough to eliminate is that whenever it's attacked but not eliminated—say by a cleaning agent such as chlorine—it reinitiates the secretions that hold it to the pipe, in effect becoming stronger than before. That's why growers frequently report that their biofilm problem seems to be getting worse over time. Once the matrix is well established, it becomes easier for other free-floating microorganisms in the water stream to stop and attach themselves to the biofilm matrix and receive nourishment (stage 4). Finally, the small populations of the biofilm continually break off with water force and move on down stream to be discharged (stage 5).

What types of organisms form a biofilm?

Pretty much any microorganism that has or had access to any part of a water system can form a biofilm—exposed hose ends, irrigation nozzles and emitters, hose bibs, faucets, tank walls, flood floor and bench surfaces, NFT troughs and baths, hydroponic grow bags. If the water outlet can be touched or touches the growing surface or the plants, it can pick up any cell to then begin morphing into the biofilm matrix, upstream or downstream. The result is than any pathogen that has ever entered into your greenhouse is quite likely lurking in your pipes at some concentration level.

Biofilm is often thought of as the green or brown algae visible in some pipes. But that's only the most visible form of a very well-developed biofilm. Most biofilms are less than 20 microns in size, so aren't visible to the human eye or only visible as an orange or brown tint. The type of heterotrophic (organisms that can't fix carbon and so depend upon organic carbon for growth) bacteria that dominate water systems and live in biofilms infect a distribution line very quickly, especially from an open line as found in abundance in irrigation systems.

Unlike bacteria such as E. coli or total coliforms, low concentrations of heterotrophic organisms will still be present after water treatment in a municipal water system or many other typical source water-treatment methods used in non-municipal systems. Within a distribution system, increases in the density of these bacteria is usually the result of bacterial regrowth. The density reached can be influenced by the bacterial level of the finished water entering the system, temperature, residence time, presence or absence of a disinfectant residual, pipe materials, surface-to-volume ration, flow conditions, the availability of nutrients for growth and the chlorine/
ammonia ratio and the activity of nitrifying bacteria.

And biofilms do love greenhouses! With untreated pond or well water sources, small diameter pipes (less than 10 in.), white PVC pipe that provides good light transmission, water that's adjusted to the perfect pH, fertilizer for a good nutrient supply and a heated greenhouses to maintain ideal temperatures, your greenhouse is a pathogen fun house!

There are three main problems biofilm can cause:

> - Reduced oxygen for your crops. Biofilm consumes the oxygen in irrigation water, often dramatically reducing critical dissolved oxygen levels to plants.
> - Increased pathogen on your crop: Biofilm dispenses potentially pathogenic microorganisms to your plants every time you irrigate.
> - Clogged emitter. Biofilm residues and chunks clog your irrigation emitters, resulting in drought-weakened or lost plants.

How can you eliminate biofilm?

That subject requires far more space and time than allotted here, so I'll provide the basics and point you in the right direction.

First, it's important to remember that biofilm destruction must be done continuously, not just occasionally, and that we can't damage or kill the plants in the process. These two critical facts make all the difference. Biofilm remediation needs to be addressed specifically and, unless specific disinfection methods and design steps are taken, it may not be accomplished through the same means used to disinfect the source water.

For years we believed that most microbial agents (chlorine, quaternaries, biocides, etc.), applied continuously or in occasional shock treatments, would eliminate biofilm. Research has proven that, even though they may be quite effective at killing free floating/planktonic microorganisms, these chemicals are unable to eliminate the foundation of biofilms—the base biofilm matrix—even at extreme concentrations and for extended periods of contact.

Some acids are able to eliminate a biofilm matrix, but they aren't practical or safe enough for plants to be used on a continual basis. These products will generally clean the top layer of a biofilm and bleach it so coloration is less visible, but there are also unfortunate side effects resulting from these types of treatments. First, when the surface layer of a biofilm is removed, the resident cells of the underlying matrix protect themselves by increasing colonizing efforts and the biofilm actually becomes worse each time you try cleaning this way. And all but one method of biofilm removal (ozone) also results in sloughing of biofilm debris that, in turn, clogs valves and irrigation emitters.

Chlorine stood for many years as an assumed biofilm solution, in part because it was able to carry a strong residual downstream in the piping system. However, in just the past few years, two key problems with chlorine were discovered. Research at Montana State University discovered that, even at very high concentrations and extended contact times, chlorine broke down in the process of reducing stage 4 and 5 of a biofilm, rendering its oxidative capacity insufficient to break down the biofilm matrix. More recent research discovered that chlorine becomes ineffective in the presence of nitrates (fertilizer).

Heat pasteurization, UV light, membrane filtration, slow sand and bio-filtration are all capable of eliminating planktonic microorganisms, but none has any impact on biofilm.

There are three practical/achievable biofilm treatment methods available in horticulture. They are in order of effectiveness:

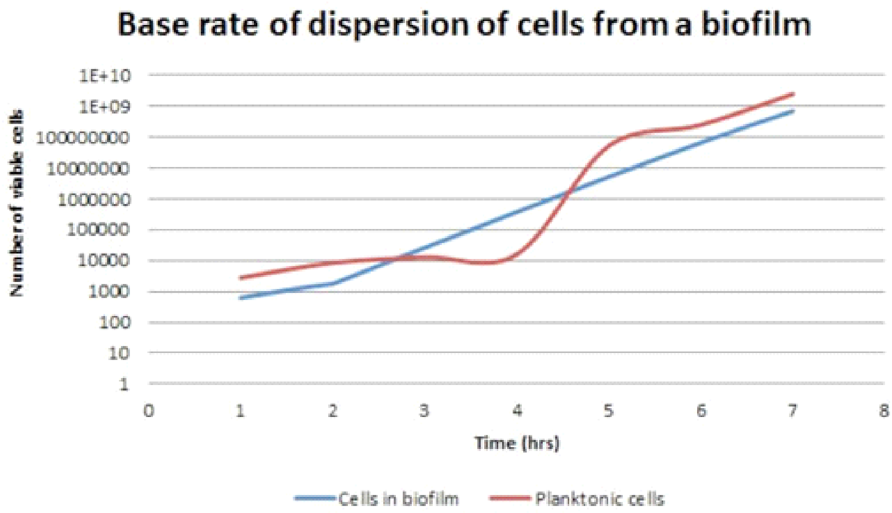
- Properly designed ozonation system
- Sufficient concentrations of activated hydrogen peroxide
- Sufficient concentrations of chlorine dioxide

These three oxidizers all share a key characteristic. After treating the source water, they're: A) able to carry a sufficient residual into the irrigation distribution system which is; B) also capable of attacking and eliminating the biofilm matrix; and C) doing so at concentrations that don't kill your plants.

When determining which of these three oxidizers is most appropriate to use, it's important to look closely at the residuals that get to the plants. At elevated levels, all three are able to deliver harmful levels of oxidizer to the plants; however, it's highly unlikely for any residual of ozone to get to the plants' roots due to its its short duration and response to pressure changes and oxidative demands of most growing medias.

Ozone also carries a substantial benefit in that when it's finished with its work, it all converts back to oxygen, significantly boosting the usable form of dissolved oxygen in the irrigation water.

Activated hydrogen peroxide is able to deliver harmful levels of oxidizer to the root system, but it's generally not used in concentrations strong enough to do so.



Chlorine dioxide must be used at concentrations very close to the toxicity threshold of most plants, so it must be monitored closely to avoid damage to root systems. All three oxidizers deserve closer examination to fully understand the pros and cons of each and this is best attained by speaking to your chosen water treatment experts.

Interestingly, when considering amortized capital cost and operating costs over a five- to seven-year period, all three solutions cost about the same on a monthly basis. A properly engineered ozone system has a high initial capital cost (which can be financed over five to seven years) but a low operating cost. Conversely, chlorine dioxide and activated peroxide both have relatively low initial capital costs, but relatively high and monthly operating costs for service and consumables. When an ozone system is paid for on a monthly lease, the monthly cash outlay is approximately the same for all three.

In considering the number one critical criteria of high-quality water—present no threat from water-born pathogens—we see that this actually requires two functions: 1) Disinfect the source water or start with clean water; and 2) eradicate existing biofilm and continuously prevent its formation in the storage tanks and distribution pipes. How that's accomplished while also meeting requirements number two and number three of high-quality water demands more time, so I'll address that in a future piece. In the meantime, here are a couple questions that deserve your
attention:

> 1. What's the dissolved oxygen level of your irrigation water?
> 2. What's the dissolved oxygen level your plants need to thrive?

For more detailed information on biofilm, feel free to download a white paper on biofilm available on the DRAMMwater website at www.dramm.com. **GT**

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