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Cleaning Irrigation Systems and Preventing Blockage Problems Coming Back

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Summary

Sediments, scale and biofilms cause inefficient function of irrigation pipes, drippers and sprinklers increasing operation costs and lowering production and water use efficiency. Algae, fungi, protozoans or their combinations are responsible for biofilms and are problematic in all production regions. Biofilm fouling is traditionally carried out using oxidising agents, chlorine dioxide, hypochlorite, hydrogen peroxide etc. Most of these products have very high environmental impacts as well as toxicity to humans, water systems and soil and are inefficient in that the biofilms will recur. These are being replaced by modern, environmentally friendly 'green' alternatives that use either physical forces such as hydrodynamics (flushing through high water flows) or the use of substances that are capable of interfering with the matrix structure of biofilms. The former is limited for systems where water is plentiful and inexpensive. The latter group includes biocatalysts (enzymes, phages) and organocatalysts (organic non-enzymes). AquaMate® is a patented organocatalyst that causes destruction of the biofilm matrix by breaking it into simple sugars and flushing out from the system whose repeated use prevents reoccurring of biofilm and is low-cost, nontoxic and non-hazardous.

INTRODUCTION

It is well documented, that irrigation lines, drippers and sprinklers may operate inefficiently when fouling occurs due to scale, sediment and/or biofilms (Kanarek 2023). Inefficient irrigation leads to lower production, higher operating costs and lower Water Use Efficiency (WUE).

Sediment removal is a function of flocculation/filtration and not covered in this paper. Scale is caused when metallic ions are oxidised to inorganic salts and accumulate in-situ. Iron and Calcium are the most prevalent though can be removed using strong acids. This will have significant Occupational Health, Safety and Environment (OHSE) consequences due to the hazardous and dangerous nature of strong acids. Avoidance can be purchased through water treatment; pH correction, EC reduction and/or chelation of ions.

Biofilms are the key focus of this paper. Extracellular polymeric substances (EPS); glycocalyx (exopolysaccharide); biofilms; slime. These may be green, red, brown or black depending on the microorganisms forming the biofilm.

Biofilms In Irrigation Systems

Biofilms may be formed by bacteria, algae, fungi, protozoans or combinations thereof. Common phyla in irrigation systems include *Proteobacteria, Actinobacteria, Chloroflexi, Mycobacterium* etc. (Kanarek 2023). Biofilm producing organisms are endemic to all production regions, they will typically proliferate in water with higher temperature, organic matter, nitrogen and phosphorus.

Because of its universality the biofilm concept impacts virtually all the subdivisions of microbiology (including Medical, Dental, Agricultural, Industrial and Environmental). Data indicate that the highly structured biofilm mode of growth provides bacteria with a measure of homeostasis, a primitive circulatory system, a framework for the development of cooperative and specialized cell functions, and a large measure of protection from antibacterial agents (Costerton, 1995).

The complex matrices that form biofilms restrict water flow causing poor distribution of water and increase pumping energy costs. Kanarek et al. (2024) confirm that biofilms provide a possible haven for pathogenic organisms and increase their resistance to biocide control. De Carvalho (2007) discusses the bioaccumulation of heavy metals and toxic compounds that can have serious effects on food production quality and the safety of field workers. Biofilms increase long term maintenance costs as they are generally corrosive to metal and concrete pipes. it is difficult to develop a single model for the qualitative composition of biofilms in irrigation systems due to factors such as geographic location (climatic conditions), type of irrigation (furrow, drip, sprinkler), materials used in the construction of the irrigation system, age of the system, intensity of operation, origin of water, fertilizer addition, and system disinfection techniques (**Fig. 1**). Each of the factors listed can promote or degrade the presence of particular microorganisms in the biofilm community. (Kanarek, 2023).

Figure 1. It is difficult to develop a single model for the qualitative composition of biofilms in irrigation systems due to factors such as geographic location, climatic conditions, type of irrigation (furrow, drip, sprinkler etc.), materials used in the construction of the irrigation system, age of the system, intensity of operation, origin of water, fertilizer addition, and system disinfection techniques. Contrasting biofilms are shown here.

Treatments for Biofilms in Irrigation Systems

Chemical applications

The treatment of biofilm fouling is popular via very dangerous and hazardous chemical applications. Oxidising agents are typical and can provide some effect where the microorganisms responsible for biofilm are able to be oxidised. This is often not the case, as biofilms are produced specifically to protect from oxidation. This leads to incomplete control or the requirement of very high rates of chemicals to try and lyse cellular walls.

Figure 2. Products used in traditional methods of biofilm control are hazardous and often less effective than modern ‘green’ technologies. For example, Chlorine dioxide (ClO_2) is an effective disinfectant for oxidisable microbes, however, it is highly hazardous and explosive in air at concentration above 10% and toxic to humans at >0.8 ppm in water (A). Hydrogen peroxide is less severe in environmental impacts but has many limitations for effective use (B).

Chlorine dioxide (ClO_2) is an effective disinfectant for oxidisable microbes, however, it is highly hazardous and explosive in air at concentration above 10% (De Carvalho, 2007) and toxic to humans at >0.8 ppm in water (**Fig. 2**A). Hypochorite solutions offer some biocidal control though not effective for many anoxic biofilms. It carries with it a caveat of being an invasive measure with significant environmental impacts (Kanarek et al., 2024).

Hydrogen peroxide (H_2O_2) is a common treatment offering some biocidal control and some biofilm control. Often very high rates are required for more complete control which comes with significant OHSE and cost impacts. Whilst less severe in environmental impacts than hypochlorites (**Fig. 2B**), effectiveness of hydrogen peroxide can be limited by UV, temperature, organic matter and heavy metals (Thomas, 2021). A small amount of oxygen may permeate soils after treatment; however this is very short lived (hours), and more likely, the persistence of OH radicals will cause greater environmental issues (Watts et al., 1999).

Alternate non-hazardous modern technologies

In modern systems, the use of "green" alternatives is becoming more in vogue. Hydrodynamics uses high water flows to flush systems. This is an alternative where water is plentiful and inexpensive, though consideration must be taken in flushing the problems further downstream.

De Carvalho (2007) advocates the use of substances capable of destroying the physical integrity of the matrix, interfere with bacterial adhesion or initiate cell detachment from surfaces, and are good alternatives to biocides and/or disinfectants. The substances include biocatalysts (enzymes, phages) and organocatalysts (organic non-enzymes). Biocatalysts are generally very specific to a target and environment, whereas organocatalysts are broader spectrum and better used in dynamic systems. Kurtural (2020) advocates a novel organocatalyst, AquaMate®, that has shown to increase gas transfer in liquids (oxygen), decrease surface tension of water, and cleave hydrogen bonds. Whilst not biocidal, this causes the destruction of the biofilm matrix, breaking it into simple sugars and flushing from the system (**Fig. 3**). With repeated use, the biofilms cannot reform as the new environment does not allow adhesion and growth of the matrix. AquaMate® is a patented, novel, organocatalyst that is low cost, non-dangerous, non-hazardous and nontoxic.

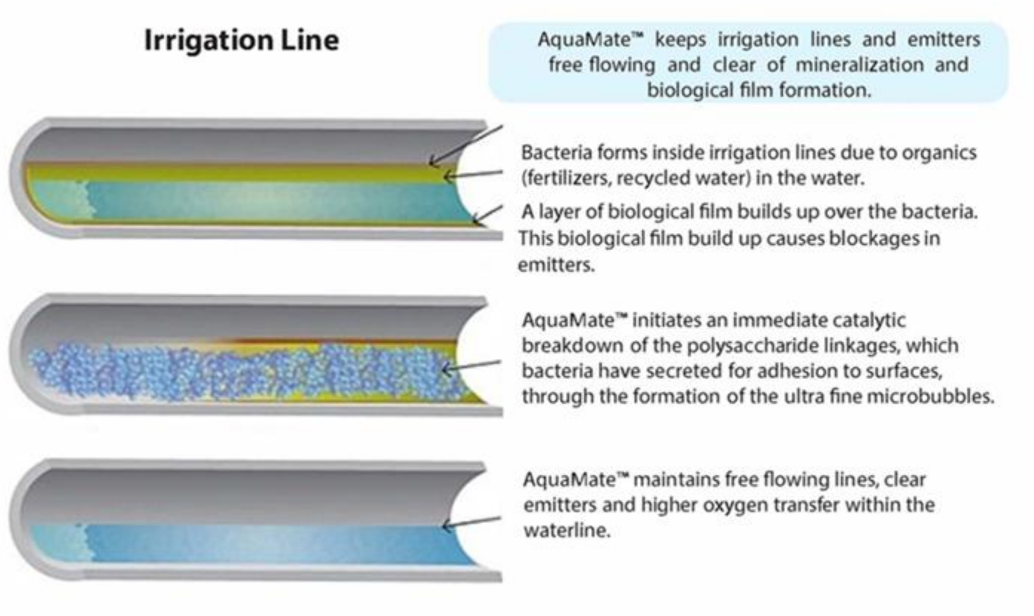

Figure 3. Benefits of AquaMate®, a patented low cost, non-dangerous, non-hazardous and nontoxic organocatalyst.

CONCLUSION

Biofilms are ubiquitous to all irrigation systems, though the level of issue is environmentally dependant. Whilst past control measures rely on highly hazardous and dangerous chemicals, modern techniques have emerged that are lower cost and safe to humans, plants, soils and the environment.

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