AQUARIUS
TECHNOLOGIES PTY LTD
WATER QUALITY CONTROL

Quality System

Quality Endorsed Company ISO 9001 Lic. No. 5403

Aquarius Technical Bulletin - No. 32

Wipe out both Legionella and Biofilm with ORP Control and Oxidising Biocides

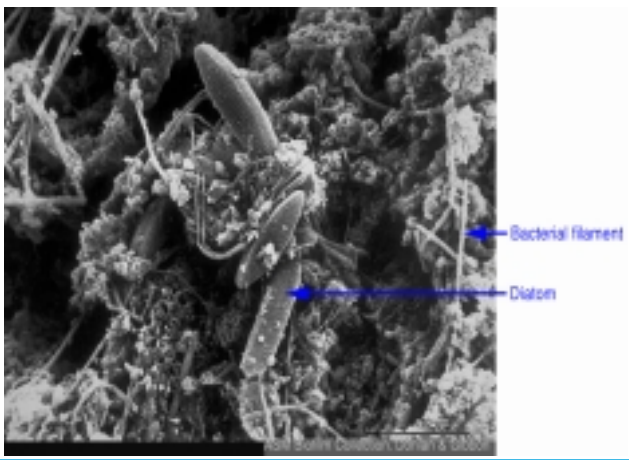
In Philadelphia in 1976, the American Legion held a bi-centennial conference to celebrate 200 years since the signing of the declaration of independence from Britain. More than 180 delegates, all staying at the same hotel, developed an acute, severe illness and 29 of them died. The final toll was 34 deaths, some of them simply passers by in the street.

We now know that what they had was Legionnaires' disease, a form of pneumonia, or infection of the lung. In the past 26 years much research has been carried out, but still numerous cases of Legionnaires Disease are reported each year by the vigilant medical system, and the majority of outbreaks involve cooling towers, which may already have a comprehensive water treatment chemical program, automatically controlled and sometimes monitored by the largest of the water treatment chemical companies.

Whilst large amounts of money are expended each year in testing both Heterotrophic Plate Counts for total bacteria and Legionella numbers in the recirculating cooling water, not a lot of effort is being routinely made to monitor biofilm microbiology, or its removal which is essential to prevention of Legionella.

Bacteria will stick to almost any wet surface in a cooling water system and will almost always produce a slimy polysaccharide matrix. This state of microorganism activity is now universally known as biofilm. Biofilm poses numerous problems in water processes, including corrosion, loss of process efficiency such as heat transfer, and is the breeding ground and "home" of Legionella Bacteria

Bacterial growth in an Industrial Condenser [1]



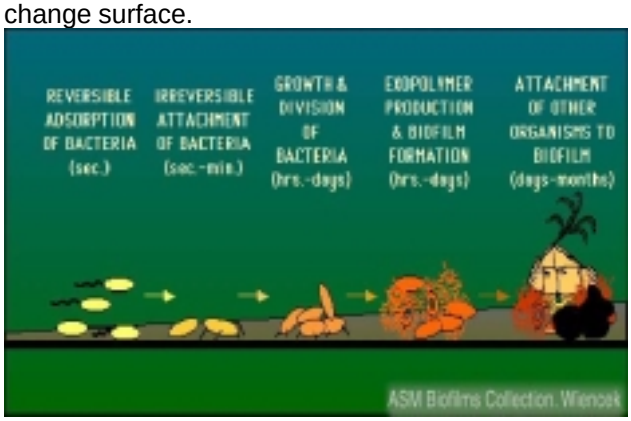
Development of Biofilms

Almost immediately after a clean pipe contacts water, organic molecules adhere to the surface. These organics neutralize the surface charge which may repel approaching bacteria.

Planktonic (free-floating) bacteria first attach themselves by electrostatic attraction and physical forces. Some of these cells will permanently adhere to the surface with their extracellular polymeric substances, or sticky polymers.

The extracellular polymers consist of charged and neutral polysaccharide groups that not only cement the cell to the pipe wall, but also act as an ion-exchange system for trapping and concentrating trace nutrients from the water.

As nutrients accumulate, the pioneer cells reproduce. The daughter cells then produce their own exopolymers, greatly increasing the volume of ion exchange surface.



A paper [3] titled "Chemical Control of Legionella " by Jennifer Miller Ph. D and Greg Simpson Ph.D - highlights the significance of Legionella and Biofilm as follows:- *"The Significance of Bacterial Biofilm - Biofilms have been shown to be a major source of Legionella in the natural environment (Bentham & Broadbent 1995; Maroa et al 1993;) Biofilm has also been implicated as a major harbour of other pathogenic diseases, Costerton 1995; Costerton & Lappin 1995; Costerton & Anwar 1994, and in particular is a major problem in the health care industry"*

As far back as 1993 - Bentham et al suggested that biofilm was the major cause of Legionella.

Research has shown that survival, growth and multiplication of Legionella in nature may also require the presence of certain protozoa.

AQUARIUS TECHNOLOGIES PTY LTD A.B.N. 94010 393 254
P.O. BOX 71, COOPERS PLAINS, Q. 4108
UNIT 1, 23 RICHLAND AVENUE, COOPERS PLAINS, Q. 4108
TELEPHONE: (07) 3274 4750 FAX: (07) 3274 4736

A further paper [4] by Broadbent in AIRAH 2000 - ***Protozoa : Trojan Horses for Legionella?;*** - *states that AS/NZS 3666 Part 3 of the standard recognises the role of biofilm in the growth and dissemination of legionella. Legionella are by nature biofilm microorganisms. In his conclusions he recommends the 'old fashioned" clean system approach, with total microbial control as the as the aim. Maintaining a clean system is very important as:*

- Only the bacteria at the surfaces (biofilm) are encountered by grazing amoebae

- Biofilm is responsible for increasing water flow friction, reducing heat transfer, and much of the corrosion that follows

- Biofilm growth is primarily by reproduction from within and from the nutrient supply

- Higher life forms are present in biofilms i.e. protozoa and amoebae

- Clean surfaces facilitates the effectiveness of the water treatment program.

Control strategies for Legionella must be able to do four things (Lee and West 1991; Ellsmore 1993; Bentham & Broadbent 1995;) namely:-

1. Inactivate Legionella and other bacteria in the bulk water.
2. Remove and prevent bacterial biofilm and inactivate associated biofilm bacteria.
3. Remove and prevent algal biofilm and inactivate associated biofilm bacteria.
4. Inactivate protozoa.

The paper [3] goes on to state that:- *"The bacteria in the biofilm has been shown to have significantly greater resistance to disinfection than bacteria in the bulk water. The fact that sessile (biofilm) bacteria exhibit a greater resistance to non-oxidising biocides has been known for some time. (Kadjasz et al. 1984). In general oxidising biocides are more effective than non - oxidising biocides in biofilm removal and control."*

The vast majority of microbiological testing is carried out on the bulk water, whilst the biofilm covering all the wetted surfaces is largely ignored for microbiological testing.

Only very gross biofilms are visible to the naked eye, most biofilms on condenser tube walls will be of the order of 0.25 mm thick, and being composed of 95% water will be largely invisible and only be noticed as a greasy feel on the finger, unless microbiological swab tests are carried out.

A biofilm of 0.25 mm thick has about the same insulation effect and reduction in plant efficiency as does a 1.0 mm. thickness of calcium carbonate scale, however when the biofilm is eliminated and prevented there is a two fold pay back, legionella can be prevented and the electricity for running costs will be reduced by 10-15% on comfort cooling systems.

Anecdotal evidence from our contacts in the Water Treatment Chemical industry is that Legionella is rarely if ever detected in systems using our ORP control, and continuous treatment with oxidising agents appropriate to the pH of the cooling water. The majority of these systems are maintained at 450 - 500 mV ORP.

Recent advances in monitoring for the amount of biofilm, e.g. Biox, BioGeorge, Onguard, etc. have been used to monitor either the biocide effectiveness - Biox & BioGeorge, or the amount of biofilm fouling by monitoring heat transfer in the case of Onguard.

Another paper [5] presented at a Biocorrosion Conference in Italy recently shows the fouling factors at various levels of ORP and here 500 - 550 mV shows nil to negligible fouling from biofilm, see the graph on next page.

A further paper [6] published in 1999 by Phillip Grayson, Ph.D. of Drew Industrial Division of Ashland titled - ***Oxidant Reduction Potential (ORP) Oxidant Control for Cooling Water Microbiological Control*** states that - *"from field experience we have found continuous oxidant fed to maintain 500 - 600 mV prevented biofilm formation on heat exchanger surfaces, and additional non - oxidising biocides may not be necessary.*

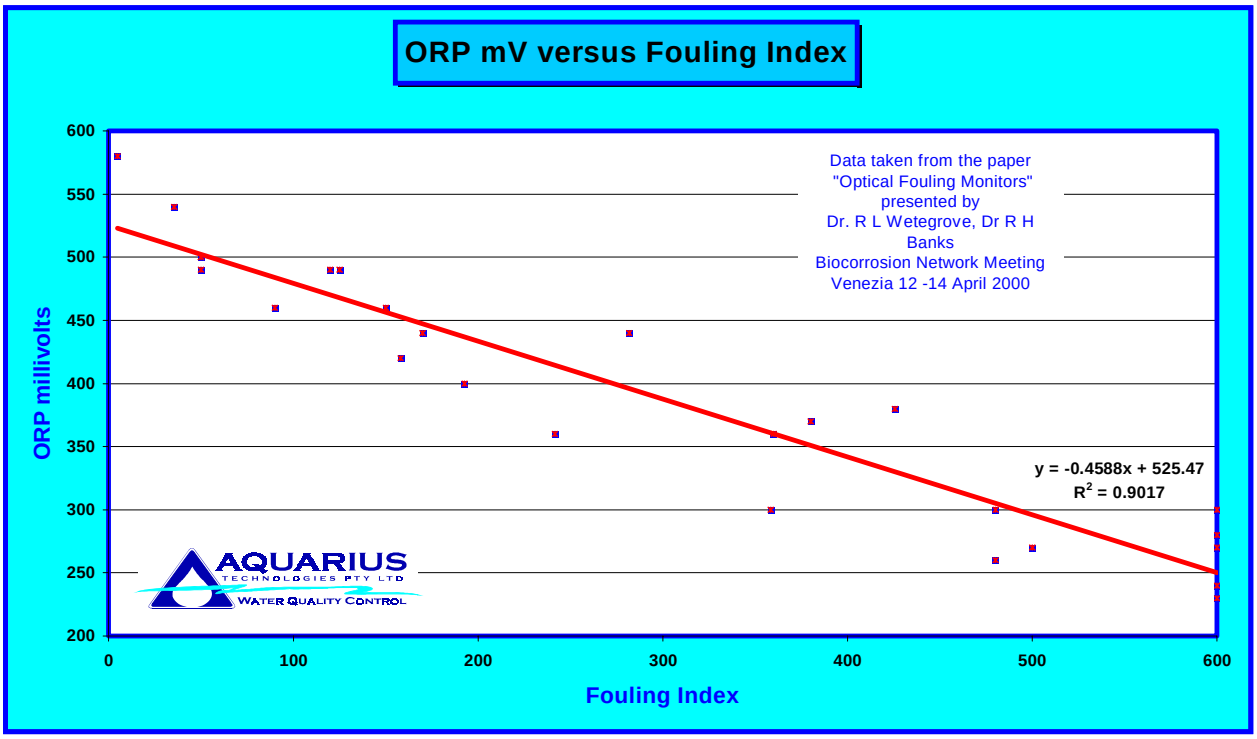
Many cooling towers become "swimming pool" clear and tower structure, piping, and heat exchanger surfaces remain microbiologically clean. Silt mud, scale, and iron oxide deposits are greatly reduced or eliminated because the biofilm is virtually eliminated. Where biofilm has previously established on surfaces ORP values of 500 - 600 mV will rapidly clean up the system."

This article was reportedly based on company experience in the US Gulf Coast area, with major cooling systems at refineries, petrochemical plants, etc.

Maintaining these higher millivolt readings on typical cooling systems should give HPC bacterial readings of less than $10^{3,}$ and LDB as "Not Detected" on the bulk recirculating water, however this information can be very misleading (even though it is a part of the Standard and very widely practised) as it is the amount of biofilm present on the wet surfaces, and the microbiological population of the biofilm which can lead up to a Legionella outbreak.

Aquarius Technologies P/L is currently developing a inexpensive **Biofilm Legionella Trap** - a 250 mm. tube packed with 3 mm glass beads is subjected to a cooling water flow of 2 -3 lts per min. After the trap has been subjected to flow for 1 - 4 weeks - the entire tube with glass beads and biofilm growth, if any, is transferred to a NATA microbiological laboratory for full analysis. After draining the tube, the weight of damp biofilm which is adhering to the glass beads can be measured, and after sonication microbiological tests can provide results as follows:-

(a) The thickness of biofilm can be reported in microns.
(b) Microscopic analysis of the biofilm crud sonicated from the beads can be reported for numbers of protozoa and amoebae, if present.
(c) Legionella counts should be carried out on the sonicated solution and reported as LDB per cm^2 area.



(d) Routine HPC should be carried out and again reported as cfu/cm^2 surface area.

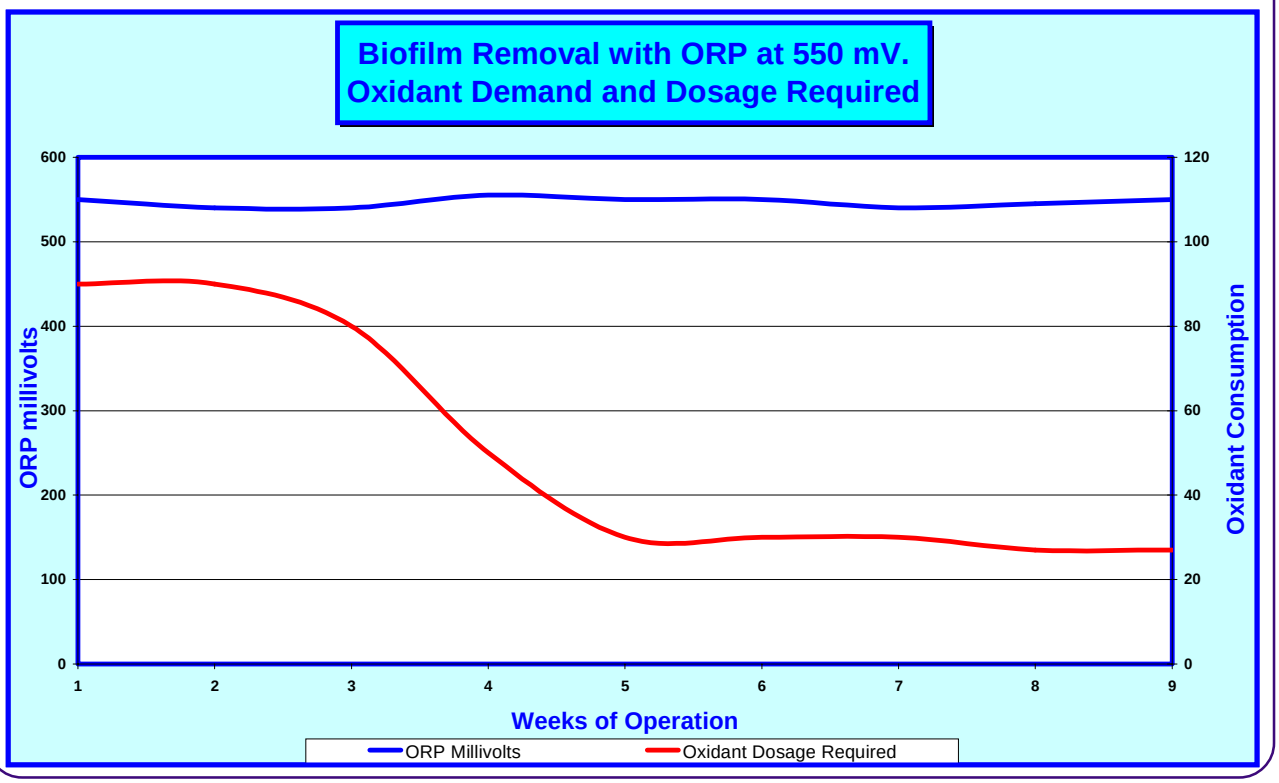
We are very confident the Biofilm Legionella Trap will be the approach of the future, as it will provide much more meaningful data than the samples currently carried out on bulk water which does not address biofilms in any way.

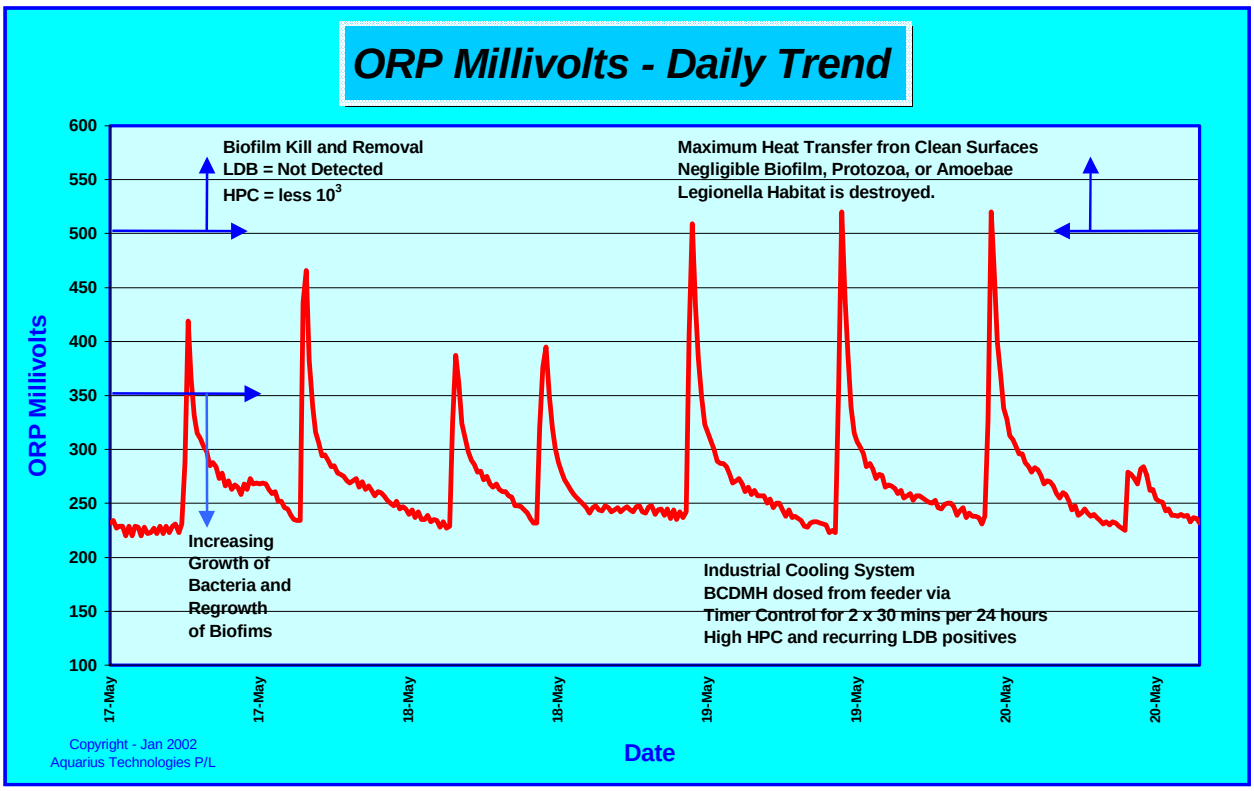
The graph below shows that the consumption of Oxidant is highest in the initial stages of biofilm removal. Biofilm removal can take a period of weeks, after which greatly reduced amounts of oxidant are need to satisfy the demand from the system.

The graph on the following page is taken from an industrial cooling tower with a recurring history of positive Legionella counts. The system had automatic bleed and inhibitor dosage, and BCDMH biocide dosed via a timer on a daily basis.

Data logging of the water chemistry at 15 minute intervals shows that the ORP “kill” level of 450 mV. is only achieved about 1/2 hour in a 12 hours period, and for 10 hrs. out of 12 hrs. the millivolt level was allowed to drop below 300 mV where rapid bacteria and biofilm regrowth growth takes place.

Using ORP to continuously maintain the oxidant level at 500 mV. has removed the biofilm and to-date a positive LDB has not been recorded.





Summary

For more than 25 years we have been aware of Legionella in cooling water systems, and at least for the past 10 years we have been educated on biofilms as the habitat of legionella.

Yet our Standards have us testing the bulk recirculating water for HPC and LDB - and we know that these results have a very poor co-relationship with LDB outbreaks, and we know that we get higher bacteria counts AFTER “DOING A TOWER CLEAN” (because we have dislodged some biofilm ?).

Now how could this be if we had cleaned the system back to bare metal, - we have not ! - in most we have only removed the gross sludge from bottom of the tower and not the biofilm and legionella habitat.

NATA microbiologists confirm that 10-20% of cooling water samples submitted each month are positive for legionella.

The Biofilm Legionella Trap is an inexpensive piece of monitoring equipment costing less than $100 and which can provide real data on the presence and thickness of biofilm, in comfort cooling systems, and the microbiological inhabitants living therein.

When biofilm has been seen to have a presence, then action should be taken to improve bacterial kill, remove and prevent further biofilms and return a two fold bonus, reduction of electricity running costs by 10 -15% and the ultimate in Legionella prevention.

ORP automatically controls the dosage of oxidant to meet the varying demands of both load and air contaminants in comfort cooling systems.

High and Low alarms can be used to alert operators to any malfunctions, and the actual ORP millivolt level can be logged to provide a round the clock historical record of disinfection control.

Acknowledgements

Many thanks to the following for their articles and education, and with apologies for any plagiarism.

1. **ASM Biofilms Collection.** - Dorian & Gibbon

2. **ASM Biofilms Collection**. - Weincek

3. **Chemical Control of Legionella** by Jennifer Miller, Ph.D and Greg Simpson, Ph.D. - Vulcan Chemical Technologies Inc. USA

4. **Protozoa : Trojan Horses for Legionella infections?** by Clive Broadbent - AIRAH Volume 54 No.9

5. **Optical Fouling Monitors** by Dr RL Wetegrove and Dr RH Banks - Biocorrosion Network - Venazia, April 2000

6. ***Oxidant Reduction Potential (ORP) Oxidant Control for Cooling Water Microbiological Control*** - Phillip Grayson, Ph.D. - Drew Industrial Division of Ashland Speciality Chemical Company.

Author

The author is Bert Topping - M. D. of Aquarius Technologies Pty Ltd - a quality assured manufacturer of automatic dosage and control equipment for the Water Treatment Chemical Industry