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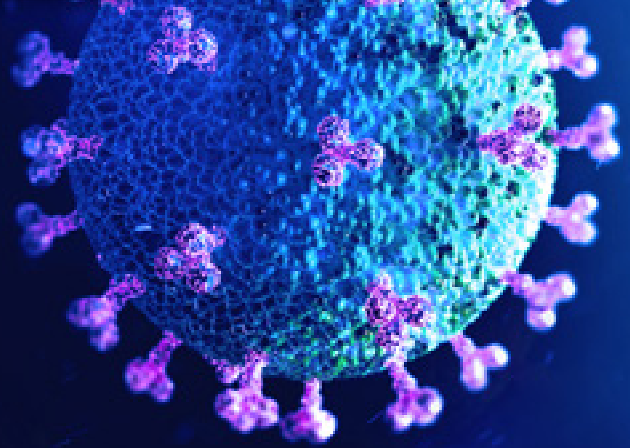

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The Benefits of a Third Generation Tetrakis(hydroxymethyl) phosphonium sulphate (THPS) Biocide to Combat Biofilms and Associated Microbial Influenced Corrosion (MIC) in the Industrial Water Treatment Industry – Case Study

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Water is the single largest resource consumed by industrial and commercial/HVAC cooling systems, these systems are routinely exposed to microbial contamination either via make up water input or through the scrubbing of airborne contaminants present in the atmosphere. Although cooling towers form the largest part of this application, industrial and commercial/HVAC closed heating and cooling circuits may also develop microbial contamination when bacteria enter via the mains water supply. Cooling towers are particularly susceptible to microbial contamination because of its optimum conditions of pH, temperature, dissolved oxygen and nutrients (debris and mineral scale) in the cooling water encouraging microbial proliferation. The microbial species entering the cooling tower will depend upon the type of make-up water being supplied. Typically, mains water would be considered the lowest source of microbial re-infection, but it should not be assumed that this is "sterile", as often mains water can contain biofilm-forming species such as *Pseudomonas aeruginosa* and the hazardous *Legionella pneumophila*.

Various microbial species (of which bacteria are predominant) exist in the cooling water systems and when present in the free-floating form, are referred to as planktonic bacteria. These species will migrate through the water phase until flow rates reduce or an obstruction prevents onward movement. At this point, the bacteria fall to the surface and are referred to as sessile. Often the first species to do this are the Pseudomonas spp.. Sessile bacteria (in particular Pseudomonas spp.) attach to surfaces using hair-like structures known as pili prior to secreting a polymeric glue-like substance known as a biofilm. The biofilm increases in thickness as debris, mineral scale, corrosion products and other microorganisms fuel the rapid multiplication of bacteria established within the biofilm micro-community **(Figure 1)**.

As the microbial community develops, biofilms can become several millimetres thick and can impact on heat transfer within a cooling system thus reducing the efficiency of cooling, or more serious, contribute to surface corrosion. Corrosion of metal surfaces related to the activities of bacteria (in particular anaerobic bacteria, e.g. sulphate reducing bacteria) is known as microbial influenced corrosion (MIC). Left unchecked, MIC could result in serious and costly damage to a cooling systems infrastructure and pinhole leaks may occur.

How can bacteria and biofilms be controlled?

It is important to implement a biocide dosing strategy to maintain low levels of bacteria. Low bacteria levels should reduce biofilm development, which, in turn, should prevent hazardous species such as *Legionella pneumophila* (entering via mains water top-up) from settling and multiplying.

A wide range of biocides are available for the control of microorganisms associated with biofilms. Biocides used to control microorganisms within cooling towers and other water systems are classed as oxidising or non-oxidising biocides. As biofilms act as a protective layer, it is sometimes difficult for oxidising biocides (chlorine or bromine chemistries) to penetrate the glue-like matrix and fail to reach the protected sessile bacteria. Very often the concentration required to be effective may be so high that it becomes corrosive to metal surfaces and an alternative non-oxidising biocide may be required.

There are many non-oxidising biocides of which Tetrakis(hydroxymethyl) phosphonium sulphate (**THPS**), Glutaraldehyde (**Glut**), 2-Bromo-2-nitro-1,3-propanediol (**Bronopol**) and the isothiazalone, 5-chloro-2-methylisothiazol-3(2H)-one (**CMIT**) are a few of the key actives used in cooling tower process waters. When selecting the best biocide active to use, it is important to consider a biocides mode of action. For example, if a system has a short contact time, a fast-acting biocide may be required. The ability of a biocide to penetrate an established biofilm to kill sessile bacteria is also paramount in the success of reducing the presence of potentially harmful species both to humans but also the system structure.

Comparison of THPS performance to water treatment biocides when targeting biofilms

THPS as a biocide active has an established history for use in cooling towers and oilfield industries for over 30 years and has proven extremely effective against *Legionella pneumophila*, general heterotrophic bacteria, sulphate reducing bacteria (SRB), algae and the Legionella's host, protozoa. More recently, THPS has been successfully used in closed heating and cooling systems to control biofilms and SRB. Advances in chemical formulating of THPS have improved and a "3rd generation THPS" has been developed which is able to penetrate biofilms and target sessile bacteria whilst still within the biofilm. The advanced THPS formulations leave the biofilm intact, reducing pipe and filter blockages normally associated with a disrupted biofilm. For example, in closed heating and cooling systems containing terminal units, this is of benefit as biofilm containing live bacteria become trapped and growth occurs, often causing corrosion or blockages.

Figure 2 illustrates the performance of THPS compared to other non-oxidising biocides against the biofilm-forming *Pseudomonas aeruginosa* bacteria isolated from the recirculating water of a cooling tower.

Figure 1: Biofilm formation on surfaces.

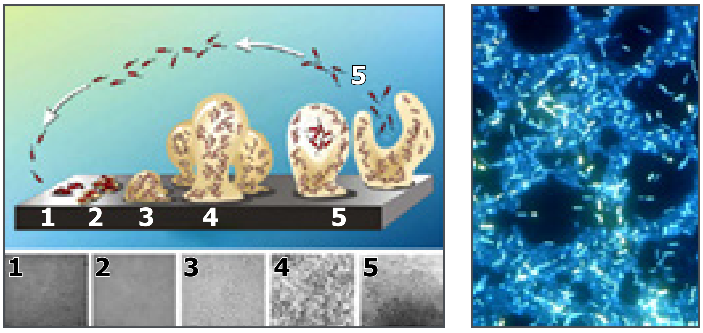

Figure 2: Performance of biocides in cooling tower water.

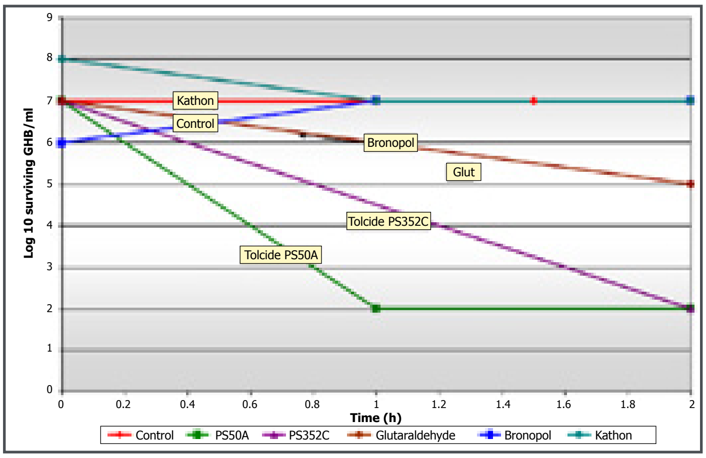

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Figure 3: Comparative sessile tests to indicate improvements by formulating THPS.

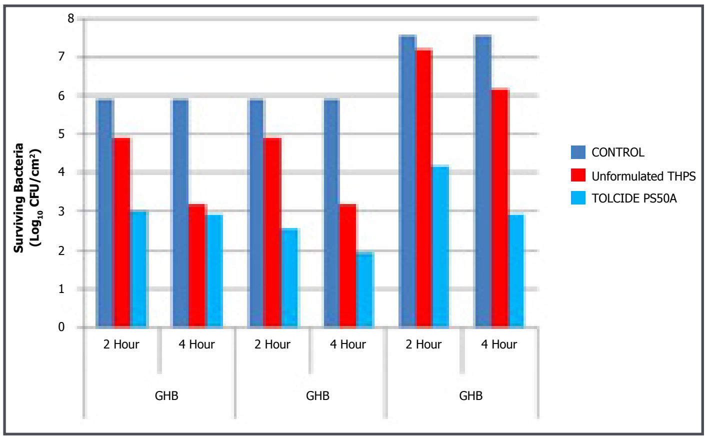


Figure 4: Biocidal activity against Legionella pneumophila when dosed at 40mg/l.

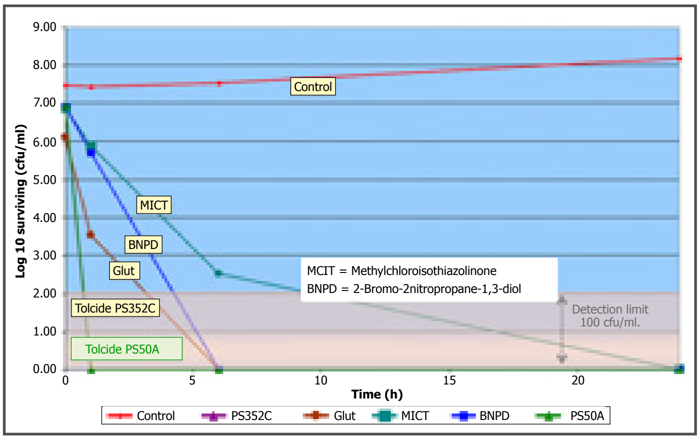


Figure 3 illustrates how THPS, as an active, can be enhanced by careful formulating to give an improved biocidal effect against bacteria within an established biofilm. The data represents comparative data for 50mg/l THPS (as active).

Tolcide® PS50A is the 3rd generation formulated THPS and both graphs illustrate its improved biocidal performance especially against bacteria associated with a biofilm. This data suggests that the speed at which THPS kills the bacteria present within a biofilm will be effective at preventing MIC of metal surfaces within open or closed cooling systems thus reducing damage litigation.

Control of *Legionella pneumophila* and its host *Tetrahymena pyriformis* by THPS

An independent study cited by Berman et al (2007) showed 40mg/l of both formulated and unformulated THPS reduced Legionella populations within 1 hour of dosing **(Figure 4)**. BNPD, CMIT and Glutaraldehyde required longer to achieve the same level of inactivation.

THPS has been shown to target the protozoa which are known to harbour Legionella pneumophila in cooling towers. Independent studies cited by Berman et al (2007) showed 50ppm THPS to be effective at killing *Tetrahymena pyriformis* within 24 hours, hence eradicating the host for *Legionella pneumophila* from cooling towers water systems **(Figure 5)**.

Figure 5: Biocidal activity against Tetrahymena pyriformis and Acanthamoeba costellani over a 24-hour period.

Tetrahymena pyriformis | *Acanthamoeba castellani*

Effect of THPS versus *Tetrahymena pyriformis*

CONTACT TIME (hours)	**THPS** CONCENTRATION (mg/l)	
	50	100
0	Cells Healthy	Cells Healthy
0.33	Cells Compromised	Cells Severely Compromised
3	Cells Severely Compromised	Total Kill
6	Cells Severely Compromised	Total Kill
20	Total Kill	Total Kill

Effect of THPS versus *Acanthamoeba castellani*

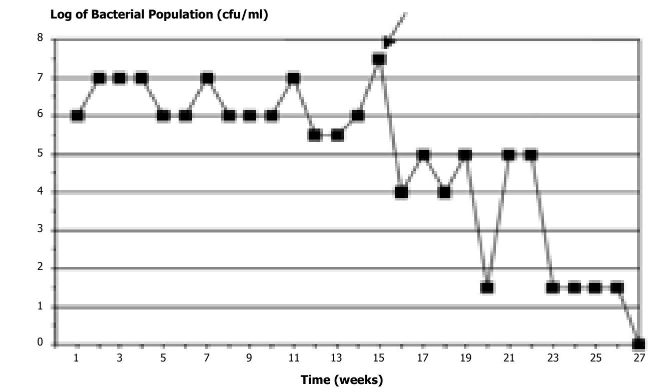
CONTACT TIME (hours)	**THPS** CONCENTRATION (mg/l)	
	50	100
0	Cells Healthy	Cells Healthy
1.0	Some Cells Compromised	Cells Severely Compromised
2.0	Some Cells Compromised	Cells Severely Compromised
5.0	Some Cells Compromised	Cells Severely Compromised
24	Total Kill	Total Kill

Control of algae in cooling towers

Cooling towers often support algal growth due to the presence of daylight on the external structures. The environment around the pack material, i.e. water, optimum temperature, nutrients, all encourage algal growth on support structures and the pack. Formulated THPS is extremely effective at controlling algae, requiring 10 - 56mg/l THPS to achieve total kill of different algal species **(Figure 6)**.

Case Study – Cooling Tower

The cooling water within a 24m³ closed recirculating cooling system at a chocolate factory contained a high organic content. Several proprietary biocides had been tried and all failed to control the bacteria species within the water system. The water had to be manually drained on a daily basis which incurred cost due to down time. 35mg/l of formulated THPS was dosed twice a week to maintain a system concentration of 70mg/l.



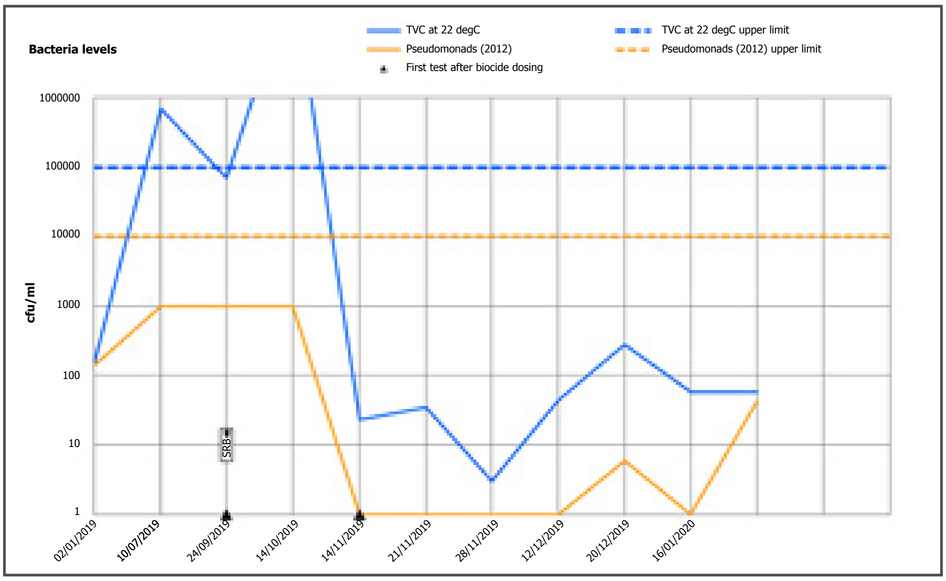
The initial treatment resulted in a 3-log reduction of bacteria and subsequent treatments brought the system under full control without the need to replace the system water. An onsite test kit was used to assist in determining the presence of THPS within the cooling system. THPS test kits are able to detect down to 10ppm using a simple iodometric titration method and this should allow for an accurate assessment of whether the biocide remains effective over time.

Figure 6: Biocidal activity against seven algal species commonly associated with open cooling towers and water storage tanks.

Organism	Refernce Number	(Hrs)	Effective Concentration (mg/litre ai THPS)
Anacystis nidulans	Wild Strain	2	26
Aphanocapsa sp.	Wild Strain	24	26
Chlamydomonas eugametos	Wild Strain	5 days	56
Chlorella emersonii	Wild Strain	24	48
Nostoc mac	Wild Strain	24	32
Phormidium laminosum	Wild Strain	4	27
Zygnema cylindrica	Wild Strain	24	45

Case Study – Closed Chilled Water System

A new build office building developed high levels of bacteria within the chilled water system. Several attempts had been made to reduce the contamination and it was proposed that the system undergo a full re-clean and flush. All the water chemistry was within accepted limits of the BSRIA BG29/2012. Hence the use of fast-acting THPS was proposed and a dramatic drop in bacteria counts was achieved after a second dose. The system remains under control and is fully operational.



Conclusion

Field studies and laboratory testing demonstrate that 3rd Generation formulated THPS is an ideal biocide for controlling pathogenic and damaging biofilm forming micro-organisms in open cooling systems and closed systems. With proven efficacy against *Legionella* spp. and *Pseudomonas* spp., combined with an excellent environmental profile due to its rapid breakdown to non-persistent bi-products, 3rd generation formulated THPS is an ideal biocide to achieve microbiological control while maintaining limited environmental impact. The added benefit of solid form formulated THPS for use in open and closed heating and cooling systems means that water treatment service providers can now offer significant benefits to the owners and operators of these systems reducing overall environmental impact whilst not compromising on biocide performance and system protection.

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