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Assessment evaluation of geothermal cooling water systems using Isothiazolinone, a non-oxidizing biocide, to prevent biofilm formation

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INTRODUCTION

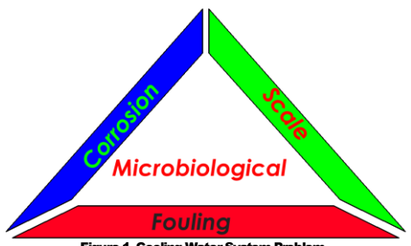


Figure 1. Cooling Water System Problem

Biofilm formation in cooling water systems is a process where microorganisms adhere to surfaces and create a slimy, protective layer. This layer, composed of extracellular polymeric substances (EPS), can reduce cooling efficiency and potentially harbor harmful bacteria. Examples of where biofilms form include pipe walls, heat exchangers, and cooling tower fill. Biofilm formation in cooling water systems is a common creates a protective matrix film, leading to fouling and reduced efficiency of the heat exchangers system, initiated to fouling, scale, corrosion, and potential health risks

The insulating effect of biofilm negatively reduces the cooling capacity of heat exchangers: a biofilm layer that is only 20 µm thick can increase heat transfer resistance by 7%. Microbiologically induced corrosion represents another often-neglected threat that can lead to downtime for costly maintenance and repair (Christina M,1981).

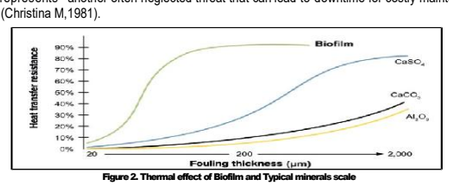
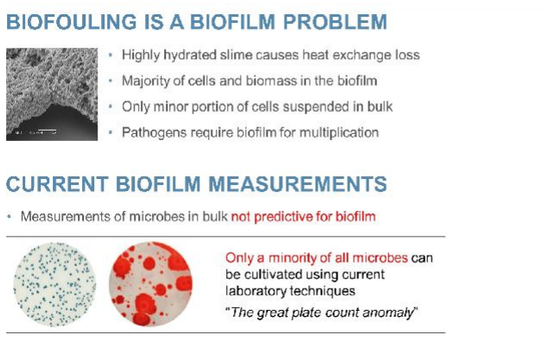


Figure 2. Thermal effect of Biofilm and Typical minerals scale

It is estimated that 20-50% of all corrosion originates from microorganisms. The fact is that biofilm causes many more problems in industrial cooling water systems than individual microorganisms. The figure below shows the effect of Biofilm on heat transfer efficiency. (Christina M,1981) .



Biofilm formation not only leads to fouling issues but also results in corrosion and scaling problems due to the utilization of chemicals (C, H, O, N, S) by sessile microorganisms in fluids.

Cooling System Issues	Biofilm	Iron Oxidizing Bacteria	Sulfate Reducing Bacteria	Acid Producing Bacteria	Pathogenic Bacteria			
					Pseudomonas	Legionella	Algae	Fungi
Heat transfer resistance	•	•			•		•	•
Reduce cooling efficiency	•				•		•	•
Equipment fouling	•	•	•		•		•	•
Increase corrosion rate	•	•	•	•				
Wood tower structure decay	•	•	•	•				•
Health risks	•				•	•		

Figure 3. Problems caused by Biofilm and other microorganism

METHODS

This paper investigates the effectiveness of Isothiazolinone as a non-oxidizing biocide within geothermal cooling water systems to manage biofilm proliferation. Solenis has implemented a detailed bio-audit program across various cooling water systems at geothermal operations in Indonesia. The collaboration between Solenis and geothermal operators has engendered a culture of innovation and ongoing improvement, ultimately fostering the responsible stewardship of geothermal resources to be more reliable and profitable.

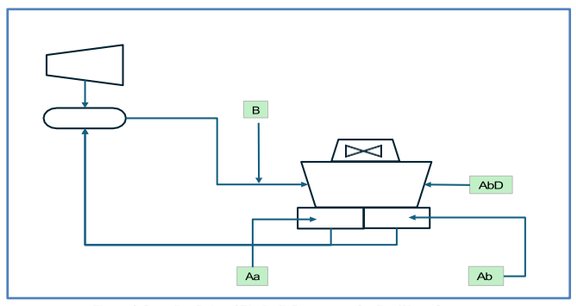


Figure 4. Sampling Point of Bio-Audit Program at Cooling Water System

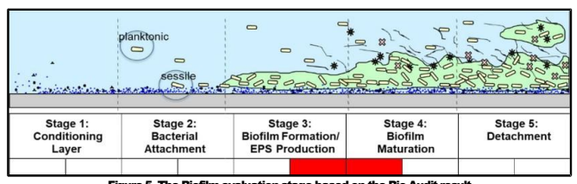


Figure 5. The Biofilm evaluation stage based on the Bio-Audit result

Microscopic examination is conducted to ascertain the entire spectrum of microbial populations residing within the cooling water system. This diverse assemblage includes organisms such as filamentous bacteria, filamentous algae, protozoa, Rotifer, sulfate-reducing bacteria (SRB), sulfate-oxidizing bacteria (SOB), green algae, nematodes, aerobic bacteria, and anaerobic bacteria. Additionally, we evaluate the status of biofilm development based on the findings from microscopic examination and quantitative plate count analysis to identify the stage of Biofilm status Below is a sample of the critical Biofilm stage in a cooling water system.

RESULTS

No`	Items	Geothermal Cooling Water							Target
		Customer A	Customer B	Customer C	Customer D	Customer E	Customer F	Customer G	
1.	Geothermal System	Flash Geothermal	Flash Geothermal	Flash & Binary Geothermal	Flash Geothermal	Flash Geothermal	Flash Geothemal	Binary and	
2.	Biocide Treatment Program	Isothiazoline and Bio-dispersant	Isothiazoline and Bio-dispersant	Isothiazoline, oxidizing biocide and Bio-dispersant	Isothiazoline, THPS and Bio-dispersant, scale dispersant	Isothiazoline, oxidizing Biocide, and Bio-dispersant	Isothiazoline , Fast killing biocide and Bio-dispersant	Glutaraldehide and Bio-dispersant	
3.	Injection Mode	slugdose weekly basis, biodispersant (continue)	slugdose weekly basis, biodispersant (continue)	slugdose weekly basis, biodispersant (continue)	slugdose weekly basis, biodispersant and scale dispersant (continue)	slugdose weekly basis, biodispersant (continue)	slugdose 10 days cicle basis, biodispersant (continue)	slugdose fortnighly basis, biodispersant (continue)	
4.	Caustic injection	continue	continue	continue	continue	continue	continue	continue	pH neutral
5.	Sessile SOB Bacteria Population -Microscopics	dominant	dominant	dominant	dominant	dominant	dominant	Not detected	Not present
6.	Nitrifying/Denitrifying bacteria activity	high	Very high	Very high	Very high	high	Med - high	Not detected	Not present
7.	Planltonic Viable Count Aerobic Bacteria	10E+4 – 10E+5	10 E+3 -10E+4	10E+3 – 10E+4	10E+4 – 10E+5	10E+3 – 10E+4	10E+4	10E+4	No specific target
8.	Planktonic Viable Count Fungi	10 E+1	< 10E+1	10E+1	10E+1	10E+1	< 10E+0	< 10E+0	No specific target
9.	Sessile Nematode - microscopics	present	present	present	present	present	present	Not present	Not present
10.	Biofilm Stage	4	4	4	4	4-5	4	2-3	3 max
11.	Common Problem Happen at Customer Side	Wood decay, broken filler and SOB bacteria very dominant, Caustic consumption increase, Reduce 1% MW efficiency	SOB bacteria and Algae dominant , Caustic consumption increase, Replace cooling water filler	SOB Bacteria very dominant, Algae massive, heavy fouling at filler system,Caustic consumption increase	Broken Filler, Reduce the Condenser vacum system, Reduce MW by 1.5 MW, Replace cooling water filler	SOB bacteria very dominant, Caustic consumption increase almost 2-times from normal, Heavy fouling at filler system	SOB bacteria very dominant, Caustic consumption increase almost 2-times from normal, Algae map, Replace cooling water filler	none	

Figure 6. Summaries of Bio Audit from some geothermal cooling water systems

The customer has the following issues;

- Increasing the delta temperature in the condenser system
- Increasing the pressure drop in the vacuum system
- Population SOB bacteria grow massively in the cooling water concrete system
- Replacement cooling water filler system regularly
- Algae grow on the surface area of the cooling water system and strainer system before the suction pump, as below picture.



Figure 7: SRB bacteria population from customer A, B and C

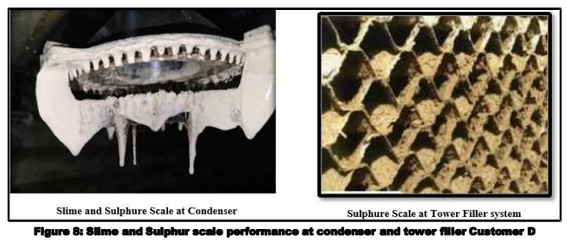


Figure 8: Slime and Sulphur scale performance at condenser and tower filler Customer D

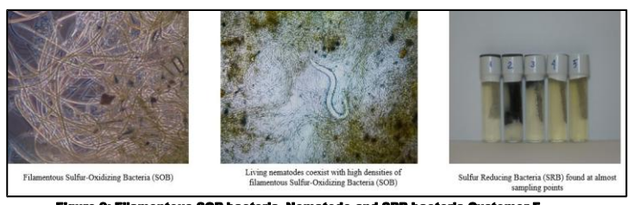


Figure 9: Filamentous SOB bacteria, Nematode and SRB bacteria Customer F

No	Sample Location	Bacteria	Fungi	Protozoa	Algae	Non Biological Organics	Inorganics	Remark
1.	Filler CT to Condensate	Filamentous	ND	Rotifer	Filamentous	detected	detected	Very Dominant : Filamentous Algae, Unicell Algae, Filamentous SOB Bacteria, SRB
		Unicellular			Unicellular			
2	Suspended Solid sample #2 HVP	Filamentous	ND	ND	ND	detected	detected	Very Dominant: SRB, Organics
3.	Biofilm stage							4

Table 1: Summaries of Microscopic Examination from Customer E

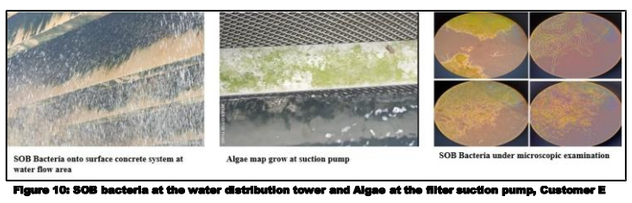


Figure 10: SOB bacteria at the water distribution tower and Algae at the filter suction pump, Customer E

Date	CT#	Locations	Visual	Sessile Mcroorganisms	Phase Contrast Microscopics	Estimated Biofilm Stage
11-Feb-25	Customer F	Basin	Green to brown, biofilm look, deposits	Unicellular Bacteria	Detected	4
				Filamentous Bacteria (SOB)	Detected, Predominant	
				Green Algae (?)	Not detected	
				Filamentous Algae	Not detected	
				Protozoa	Detected	
				Rotifer	Detected	
				SRB	Not detected	
				Inorganic	Detected	
				Organic-sulfury look	Detected	
				Nematode	Detected	

Table 2: Summaries of Microscopic Examination from Customer F

CT#	Locations	Visual	Sessile Mcroorganisms	Phase Contrast Microscopics	Estimated Biofilm Stage
1	Basin	A thin layer, collectables, white color dominant with black spotted	Unicellular Bacteria	Detected	2-3
			Filamentous Bacteria	Not detected	
			Unicellular Algae	Not detected	
			Filamentous Alge	Not detected	
			Protozoa	Not detected	
			Rotifer	Not detected	
			SRB	Detected	
			Inorganic	Detected	
			Organic	Detected	
2	Basin	very thin layer, uncollectabled			1-2

Table 3: Summaries of Microscopic Examination from Customer G

DISCUSSION

Refer to another six customers' cooling water performance results, Isothiazolinone unable to prevent development of Biofilm growth on the maximum target stages at < 3. The reason for the ineffectiveness of Isothiazolinone due that most of the cooling water systems in the geothermal industry have sulfide contamination from nature. In the cooling water with sulfur contamination, certain sulfur compounds, such as sulfides, can degrade Isothiazolinone. The Isothiazolinone ring is susceptible to a nucleophilic attack from sulfides, which can break the ring and form simple organic acids, then Isothiazolinone becomes ineffective as biocide.

Sulfate Reducing Bacteria (SRB) and Sulfate Oxidizing Bacteria (SOB) in high-sulfate environments will grow massively since Sulfide in the geothermal cooling water system serves as a food resource for both types of bacteria to grow mutually. The Biofilm stage status at cooling water from six customers has achieved on the stage more than 3 stages; this biofilm will function as a protective material that hinders Isothiazolinone penetration and activity against the bacteria. In most anaerobic conditions (low flow area, dead end zone, and stagnant area, like at cooling water filler systems) favoring SRB bacteria grow exponentially, and in certain SRB species to develop resistance to biocides also contributes to the ineffectiveness of Isothiazolinone in controlling bacteria population.

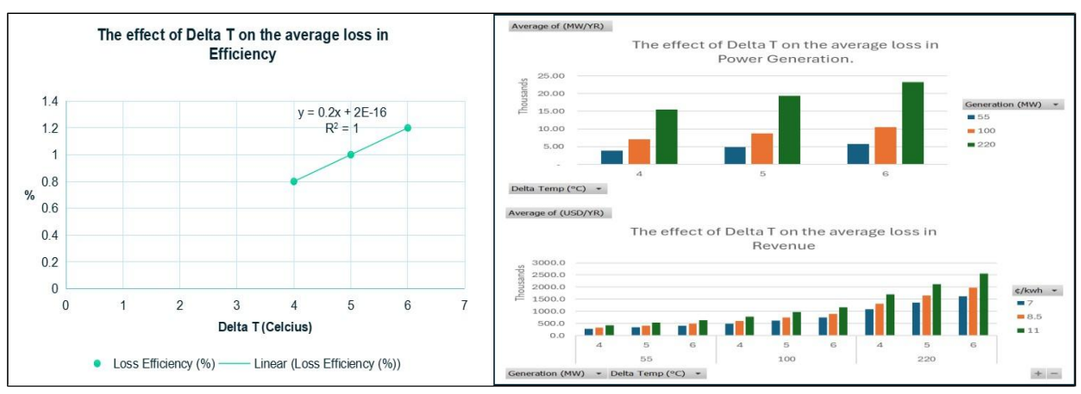
Most of the cooling water make up in the geothermal industry comes from a condensate water system. Where the most likely condensate system operates in low pH conditions, and low pH in the cooling water system also contributes to reducing the stability and performance of Isothiazolinone as a biocide.

According to the data presentation above, the conclusion from this study was drawn a comprehensive comparative study was drawn between Isothiazolinone and others biocide programs, but the facts and data of the seven customers cooling water system audited, six customers showed failure to maintain the Biofilm stage at maximum 3 stages (all at > 4 stages), and coincidentally, all the six customers used Isothiazolinone as a non-oxidizing biocide. Only customer G successfully controls their cooling water operation properly.

The effect of decreasing delta temperature operation in the cooling tower system on the loss in efficiency and loss of revenue in the power plant generation is described below. Every 5 degree delta T difference will cause 1% reduction in power plant efficiency.

CONCLUSION

Analysis of technical field data, microscopic examinations, and biological audit outcomes revealed that Isothiazolinone was unable to control biofilm buildup in the tested systems. In some instances, its application resulted in increased chemical treatment costs exceeding USD 80,000 per year and a reduction in power plant MW output by over 1%. These findings suggest that alternative biocide strategies should be considered to optimize system performance and cost-efficiency.



Graph 1: The effect of delta T on the average loss of MW efficiency and revenue loss per year

DISCLAIMERS

The authors do not intend to suggest that Isothiazolinone is not a good biocide; this technical paper aims to provide information and understanding regarding **"Assessment evaluation of geothermal cooling water systems using Isothiazolinone, a non-oxidizing biocide, to prevent biofilm formation"**. The Authors are not responsible for the interpretation or use of information in this paper outside the context of the intended research. The result of this study may vary in the field and does not guarantee the same success for every application of Isothiazolinone in the field of non-geothermal cooling water system industry.

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