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# CONTROL OF BIO-FOULING IN GROUND AND SALT WATER PLATE HEAT EXCHANGERS USING IODINATED BUBBLE INFUSION. TWO CASE STUDIES

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## ABSTRACT

The fouling of plate heat exchangers (PHE) represents a maintenance challenge for facilities that use them for cooling water systems and power generation. Microbes in supply side cooling water proliferate when conditions are conducive leading to bio-film formation. Fouling diminishes system functionality causing energy loss, heat transfer degradation, environmental impacts and added expenditure which in the USA alone may account for over $4 billion (Wang et al., 2007).

Many facilities wait for an exchanger to foul before performing remediation due to the costs involved. Although there are various methods for cleaning a fouled exchanger, there are few protocols that retard foul advancement. Immediately after bio-slime begins to form it starts to effect heat transfer and reduces system efficacy. The need to disrupt bio-foul formation is apparent. This paper represents the observational findings of two sites using i2 infusion to retard bio-film growth.

## INTRODUCTION

Bacteria will adhere and colonize on surfaces within a fluid. Bio-films are produced to protect the colony and as the biomass mature and thicken, they reduce the flow space between the PHE plates. The i2 Bubble Infusion method was developed to retard bio-film formation within the plastic tubing that supplies clinical water during dental procedures. The methods developed by i2 Air Fluid strips iodine vapor, in sufficient quantities from a proprietary resin bead surface for elution into an air stream, so as to provide a targeted disinfection via an iodinated bubble. It has been shown to rapidly reduce counts of *Pseudomonas A.* to zero in minutes. Equally effective against other pathogens, it has the added benefit of leaving a very low fluid residual.

Ground and sea water, when used for cooling, may present a myriad of microbes capable of forming bio-films within a heat exchange device. In 2007, i2 Air Fluid Innovation was contracted to develop and test an i2 infusion based protocol to help maintain a rapidly fouling 300 gpm fresh water geothermal system at SMSC, an electronic manufacturing concern on Long Island, NY where *Gallionella*, an iron reducing bacteria, was the primary fouling agent. Due to the results achieved at SMSC, in 2011, i2 Air Fluid was contracted to provide similar protocols to a 150 gpm saltwater PHE system in Hamilton, Bermuda. Both sites presented the opportunity to observe the long term effects of i2 infusion on progressive fouling. The Long Island site was monitored for 5 years and the Bermuda site for over one year. In this work, the effects of the i2 infusion techniques will be investigated in an industrial setting and the use of iodinated bubbles for foul retardation will be discussed.

## BODY

Within seconds after exposure to supply water, clean plates within the PHE begin to foul. Salts and minerals precipitate forming a surface on which planktonic bacteria may adhere. After only hours, the bacteria, through polysaccharide generation, develop a protective barrier called bio-film. Extraction of nutrients from water and plate surfaces, allows the bio-film to mature and thicken, extending into the flow space between the plates reducing water volume and increasing back pressure. Even immature bio-films within hours can act as a thermal barrier, degrading heat transfer. The increase in pressure drop is a result of the narrowing of the flow area (Wang et al., 2007) and system performance degrades over time.

Table 1. Effect on condenser mineral* deposit on efficiency loss and corresponding GHG generation

| Deposit (Inches) | % Eff. Loss | GHG(CO2) outfall** |
|---|---|---|
| .01 | 9 | 202.9 metric tons |
| .03 | 27 | 608.9 metric tons |
| .05 | 45 | 1014.8 metric tons |

Cooling Tower Institute CTI Paper No. TP239A, *Facilities Engineering Journal March 2009*
*Thermal conductivity 2.9 Bio-film thermal conductivity .6
**EPA emissions factor of 7.18 x $10^{-4}$ metric tons $CO_2$ / kWh

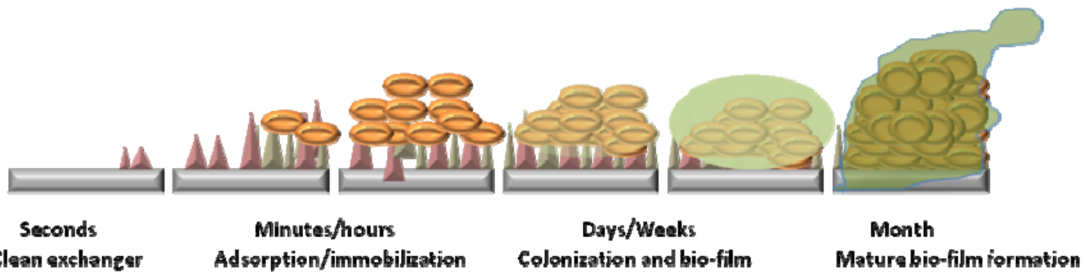


**Figure 1. Foul formation**

Iodine, a member of the halogen group, is effective both in air (Raymond, 1946), and water (Chang, S. L. 1958) as a broad spectrum antimicrobial. It inactivates microbes, as does chlorine and bromine, through oxidation of key amino acids within the cell wall. It does however, when used for water disinfection, require a relatively long dwell time due to it not being readily soluble. It is also expensive and dangerous to handle in its natural state. Iodinated resin beads have been demonstrated to be effective when used in inactivating waterborne microbes through direct contact demand where elemental i2 is transferred to the cell wall. Highly electro-positive, the bond between the molecular iodine and resin bead is such that it does not easily sublimate free iodine thus providing for an extended disinfectant life. There is a narrow “atmosphere” of elemental iodine around the resin bead surface and the patented i2 methods achieve dissolution of this gaseous iodine in sufficient quantities so as to interact with microbes downstream via a bubble contact.

Air bubbles have been found effective in disrupting foul formation within a PHE (Baek et al,.2010) as well as in medical water supply lines (de Carvalho, 2007). Mechanically disruptive, air may though accelerate the proliferation of aerobic microbes by providing dissolved oxygen. Incorporating a gaseous antimicrobial should negate this. Iodine rapidly inactivates by oxidation of amino acids within the microbe’s respiratory chain and this action is irreversible. It also has been shown to cause disruption of organic bonds. Elemental i2 is the most active disinfectant species of the iodine group through a wide range of pH and as a vapor, should offer faster cell wall/biocide interaction than that of an aqueous iodine preparation. Independent studies have shown a reduction of elevated *pseudomonas a.* counts in water to zero in less than 5 minutes whereas a liquid formulation would have required 20 minutes or more. Pseudomonas a. is a prolific and difficult bio-film former found in many aqueous environments and a key indicator for the success of any biocide (Fallis et al.).

At both test sites, rapid fouling required frequent disassembly of the PHE. The first task was to develop a method that would eliminate the need for breakdown. Drawing from previous experience in using the i2 method to clean dental waterlines, the iodinated infusion was used as part of an in-situ cleaning of the exchanger that used mild acids. It has been found that i2 infusion maintains the acidity of the cleaning solution used and this enhances the removal of formed foul. Additionally, the dynamic action of the bubbles lifted and exposed adhered bio-film. The technique rapidly reduced the approach temperature and pressure drop to what a teardown would provide in less than four hours per exchanger. The infusion device was integrated with little modification and iodinated air was infused into the supply water stream at a frequency of 5 minutes every hour. This is intended to inactivate and dislodge newly attached microbes before they form a bio-film. Bubbles may also induce turbulence, reducing sedimentary forces while increasing surface heat transfer (Donnelly et al., 2009), reducing inverted solubility and precipitation. A two hour flush of the systems was performed once every 2 months to remove inorganic or sediment not removed by the active bubbling. This cleaning protocol used the same mild acid cleaner as the initial cleaning.

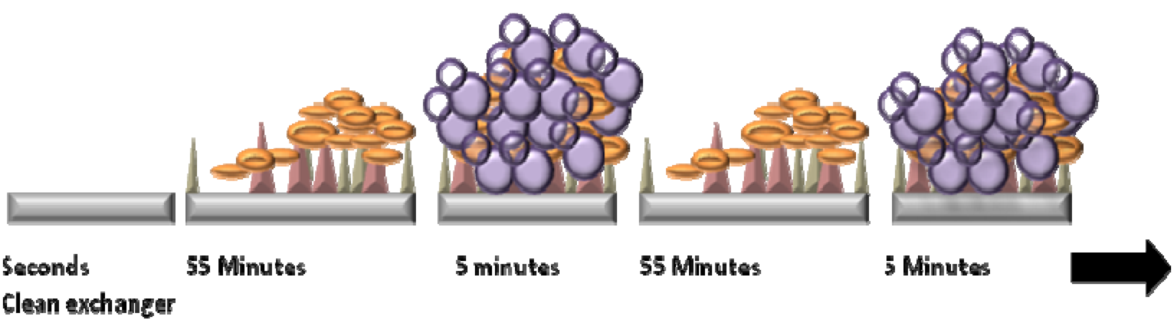


**Figure 2. Foul disruption with i2 infusions**

**RESULTS**

At both sites the infusion protocol appeared to retard foul formation and retain adequate heat transfer enough so as to require only a simple cleaner flush once every two months, negating system teardown. At the Long Island site the exchanger has not been broken down in 5 years. In Bermuda, the exchanger was broken down once during the study period. Previously, both required teardown every 2-3 months. Reduced foul formation and maintained system function was determined by the LMTD, approach temperatures and pressure drop as indicated by gauges on the system. The cleaning flush was performed by the author every two months and took approximate 2 hours to perform. The cleaner effluent contained minimal debris compared to the initial cleaning indicating reduced foul formation assumed to be due to the timed infusion.

At the Long Island site, prior the study, the pressure drop would be near 30 psi and the approach temperature would fluctuate dramatically. Additionally, prior the study, the diffusion wells would exhibit rapid fouling. During the 5 year study period and since, the LTMD remained at or near the design temperature, pressure drop was at or near 7 psi with inlet pressure ranging from 8-10 psi and outlet pressure near or less than 3psi. The cooling water outlet pipe shown in figure 3 and figure 4 was not exposed to any cleaner yet, had considerably less foul after just one year than at the start of the study due only to infusion. The recipient wells have remained clear of foul buildup during the 5 years as indicated by the low outlet pressure and recent video imaging shows no bio-foul buildup, Figure 6. This was contrasted to video prior the study that indicated excessive bio-mass in both the water volume and on screen surfaces, Figure 5. After the 5 year period, scanning electron images and metallurgical testing show no denuding of plate surfaces due to infusion. Total monthly iodine usage, as determined by cartridge weight, was under 26 grams.

**Figure 3. Outlet valve prior infusions**

**Figure 4. Outlet valve post one year infusions**


**Figure 5. Diffusion well foul**

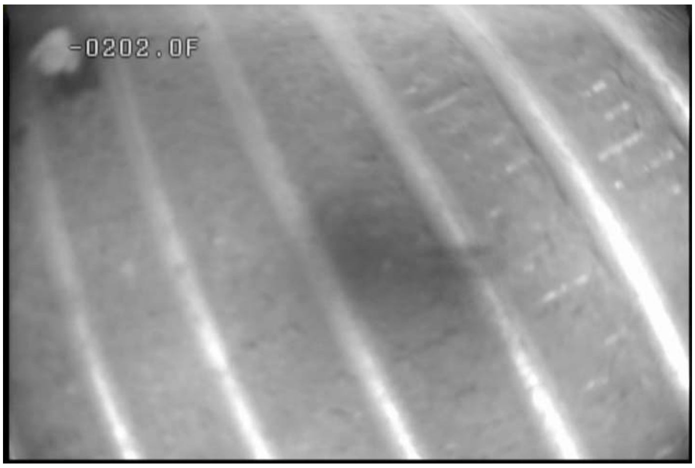


**Figure 6. Diffusion well screen after 5 years.**

At the Bermuda site, an in situ cleaning was performed early February, 2011, in lieu of a complete teardown, and the cleaning reduced approach temperature considerably. The infusion alone was able to maintain approach temperatures at or near those achieved after cleaning. Every 6-8 weeks a one hour flush was performed when approach temps would rise past a 10% increase to eliminate any foul unaddressed by the infusion. The system would typically require teardown every two months but, the daily use of i2 infusion was able to maintain approach temperatures.

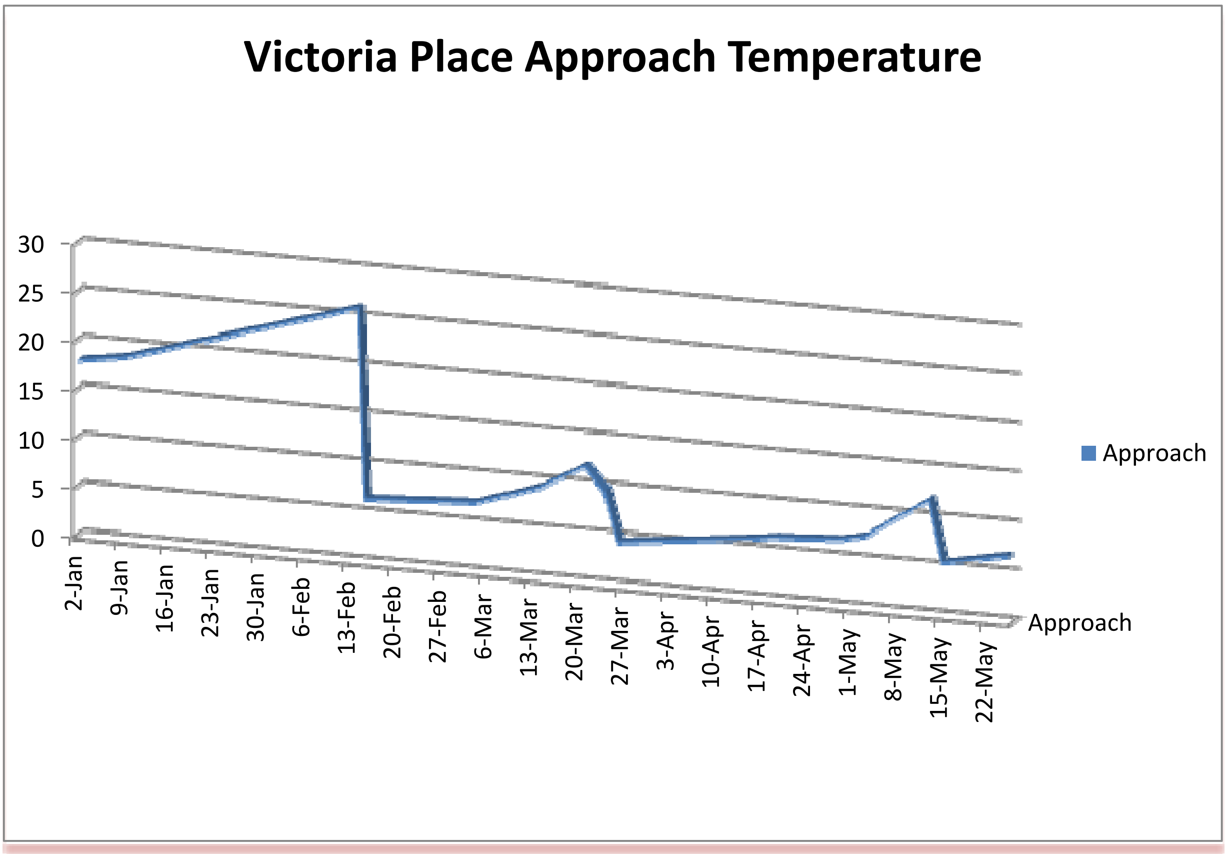


**Figure 7. Approach temperature, Victoria Place, Hamilton, Bermuda**

## DISCUSSIONS

Disassembly of a fouled PHE is both time consuming and costly. Maintaining system functionality is paramount in containing energy costs and reducing greenhouse gas generation. As indicated by this and other studies, bubbles may have a mitigating effect on foul formation as well as heat transfer. The protocol has been used as a standalone and in conjunction with mild acid cleaning to maintain plate heat exchangers of various sizes. The energy required and the cost of materials was negligible. The i2 methods appear to impart enough elemental iodine so as to not be a health or environmental concern yet provide the required antimicrobial effect.

## CONCLUSIONS

The test results indicate that i2 infusion has an effect on foul formation in small ground or sea water PHE systems without any deleterious effect to system components. It integrated easily into the existing system with little modification. The effluent iodine discharge appeared to be insignificant. The results of these and other studies have led to investigations by the US Navy as means to help retard fouling in seawater exchangers on board naval vessels and at the National Energy Laboratory, Kona, Hawaii. Although the results indicate that i2 infusion can successfully alter foul patterns, as shown in figures 8 and 9, conditions such as; type of foulant, system size and flow may impact its success and will need to be considered.


**Figure 8 Seawater flow tube no infusion**

**Figure 9 Seawater flow tube with infusion**

**REFERENCES**


Baek, Seung-Moon, Won-Sil Seol, Ho-Saeng Lee and Jung-In Yoon (2010), *Decreasing the Fouling of Heat Exchanger Plates using Air Bubbles*, Defect and Diffusion Forum Vols. 297-301 (2010) pp 1199-1204

Chang, S. L. (1958), *The use of active iodine as a water disinfectant.* J Am Pharm Assoc 47, 417-423.

de Carvalho. Carla C. C. R. (2007), *Biofilms: Recent Developments on an Old Battle.* Recent Patents on Biotechnology 2007, 1, pages 49-57

Donnelly, Brian, Tadhg S. O’Donovan, Darina B. Murray (2009), *Surface heat transfer due to sliding bubble motion,* Applied Thermal Engineering 29 (2009) 1319–1326

Fallis, K., K. Harper R.Ford, *Control of Biofouling Using Biodegradable Natural Products*
NAVAIR-China Lake, SERDP Project Number: PP1277

Raymond, W.F. (1946), *Iodine as an aerial disinfectant.* J Hyg (Lond). (1946), May; 44:359-61.

Wang, L., Sunden, B, Manglik, R.M. (2007). *Plate Heat Exchangers: Design, Applications and Performance*, WIT Press, ISBN 978-1-85312-737-3, Southampton, Great Britain.