Biofilms

TT-032-0499

The role that biofilms play in causing or contributing to a number of cooling system water related problems is widely misunderstood or underestimated. This paper will attempt to provide a level of understanding of what biofilms are, what problems they cause and the treatment approaches to dealing with them.

Biofilms are accumulations of microbial cells (algal, bacterial and fungal) and the extracellular biopolymer they produce. Bacteria in the bulk cooling water attach to metal surfaces by proteinaceous appendages known as fimbriae. The bacteria are attracted to the metal surface because organic molecules adsorbed there provide nutrients.

When a number of bacteria have attached to a surface, they begin producing a by-product called extracellular biopolymer, which consists primarily of polysaccharides and water. This material, which is approximately 90% water, can have a mass of as much as 100 times that of the bacteria themselves. This biofilm has a slippery consistency, hence its common name -- “slime.”

Problems Associated with Biofilms

A problem that biofilms cause in cooling systems that most water treaters and maintenance personnel are very familiar with is fouling. Algal biofilms foul cooling tower distribution decks and film fill where these surfaces are directly contacted by sunlight. Biofilm accumulations in these areas cause flow restrictions and result in decreased tower efficiency. Portions of the mass can also break loose and be transported to other parts of the system, causing blockages and providing nutrients for various strains of bacteria.

Bacterial biofilms develop most frequently on heat transfer surfaces as temperatures there favor the rapid growth of many strains of bacteria. Biofilm fouling of heat exchangers is a major operational problem because of biofilm’s extreme resistance to thermal conductance. Figure 1 shows the thermal conductivity values for several deposit-forming compounds compared to biofilm. A lower number indicates a greater resistance to heat transfer.

Fig. 1
Thermal conductivity comparison of deposit-forming compounds and biofilm.

Substance	Thermal Conductivity ($W\ M^{-1}\ K^{-1}$)
$CaCO_3$	2.6
$CaSO_4$	2.3
$Ca_3(PO4)_2$	2.6
Fe_2O_3	2.9
Analcite	1.3
Biofilm	0.6

In addition to general fouling, biofilms can contribute to scale formation as well. Carboxylate functional groups in the biopolymer attract calcium ions from the recirculating water and fix them in place in the biofilm matrix. There they are available to react with carbonate ions which are also present. Once this nucleation of the calcium carbonate molecule has occurred, a crystal can grow. Biofilms can also trap calcium carbonate particles that have already precipitated. These particles can then serve as crystal growth sites.

Biofilms cause or contribute to a large percentage of the corrosion that occurs in cooling water systems. Iron oxidizing bacteria can cause severe localized corrosion, and the biofilms they and other bacteria strains produce can serve as sites for the proliferation of anaerobic bacteria such as sulfate reducers. These types of bacteria produce byproducts that are acidic and cause high localized corrosion rates.

Biofilm Control

It is clear that controlling the growth of biofilms is critical in providing for the overall prevention of scale, deposition and corrosion in cooling water systems. Traditional microbiological growth control programs have focused on planktonic, or free-swimming bacteria. While monitoring and control of planktonic counts can be of value, particularly if done over time to establish a trend or profile, focusing only on this form of microbe will oftentimes provide less than satisfactory results.

First, planktonic counts are not necessarily an indication of the amount of biofilm present. In addition, free-swimming micro-organisms are not generally responsible for corrosion and fouling of heat exchange equipment. Even Legionella, which must be planktonic to infect susceptible individuals, are sustained and amplified by amoebae which are sessile, or part of a biofilm mass.

Biofilms are controlled through the use of microbicides, biodispersants and biofilm cleaners. Oxidizing biocides, such as chlorine, bromine and chlorine dioxide can be effective at providing biofilm control. When these biocides are used, it is critical that sufficient residual be maintained in the recirculating water to completely oxidize the polysaccharide mass. With bromine, and particularly with chlorine, this can often greatly increase the corrosion potential in the system. When this is the case, chlorine dioxide can be a good alternative.

Several non-oxidizing biocides can be useful in biofilm control. In particular, glutaraldehyde, THPS and polyquats are effective at penetrating biofilms and killing the micro-organisms growing there. However, these biocides will have little effect in destroying the biopolymer matrix.

For penetration *and* removal of biofims, the use of an adjunct treatment is recommended. Biodispersants are available which will penetrate and disperse biomasses. A new biofilm cleaner has recently been developed that penetrates and destroys biofilms. This new technology not only destroys the biopolymer matrix, it also attacks the attachment structures and completely removes the biomass from the metal surface.

The penetrating action of the cleaner exposes the micro-organisms growing there to the effects of the microbicide being used. This will often reduce the amount of biocide required to achieve a complete kill of algae and bacteria in the system. By leaving a bare metal surface, it will also allow the corrosion inhibitor to re-establish protection.

The biodispersant or biofilm cleaner should be slug fed to a point in the system where good mixing is assured. Addition should be made ½ hour to 1 hour prior to biocide addition. The level of biodispersant or cleaner necessary will be dependent on the amount of biofilm present. As with the biocides themselves, frequency of addition depends on the rate of re-infection, the ambient conditions and the level of nutrients available.