PUBLISHED QUARTERLY FOR THE BENEFIT OF THE WATER TREATMENT CHEMICAL USER

Volume 9 **Summer 2002**

Biofilm Costs Industry Billions

Each year, a slimy, glue-like substance costs business and industry billions of dollars in the United States alone. The substance is biofilm, a gelatinous mass that grows in the cooling towers and heat exchangers of commercial and industrial cooling water systems.

Biofilm consists of microbial cells (primarily algal or bacterial) and the extracellular biopolymer they produce. Bacterial biofilms form on pipe walls and on heat exchange surfaces. Bacteria enter a cooling system in the make-up water, and migrate to metal surfaces, where organic molecules adsorbed there provide nutrients. The bacteria attach to the surface by proteinaceous appendages called fimbriae. Once attached, the bacteria quickly multiply and begin to form "colonies". As these colonies grow, they produce a gooey polysaccharide biopolymer or "slime". The volume of slime produced can exceed the mass of the bacterial cells by a factor of 100 or more. The slime mass provides a protective environment for the survival of the organisms.

Algal biofilms form on cooling tower distribution decks and on the outer surfaces of basins and fill that are exposed to direct sunlight. Algae attach to the surfaces there in much the same way as bacteria, but they utilize CO_2 and energy provided by the sun to produce carbohydrate. They form dense, mat-like biofilms, and the carbohydrate they manufacture provides additional nutrients to support the growth of bacteria.

Once biofilms begin to form in cooling water systems, a number of problems arise. As the slime mass can quickly become quite voluminous, biofilms can impede water flow. If left unchecked, slime can completely block flow through the system.

Algal biofilms foul cooling tower distribution decks and fill, often significantly reducing tower cooling efficiency. When excessive masses develop, portions may break loose and transport to other parts of the system, causing blockage and providing nutrients for further bacterial growth.

Bacterial biofilms frequently form on heat exchange surfaces, where they can drastically reduce heat transfer efficiency. Table 1 shows the thermal conductivity of a variety of deposit forming substances compared to biofilm. A lower number indicates a greater resistance to heat transfer. Biofilm is over four times as resistant to heat transfer as calcium carbonate-base scale. A biofilm only 0.045" thick on the condenser tubes of a centrifugal chiller can result in a 35% increase in chiller electrical consumption.

Table 1

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

Formation of biofilm in a cooling water system often results in another problem – corrosion. As biofilms form, they create anodic and cathodic areas on the metal surface, setting up a basic corrosion cell. Some anaerobic bacteria produce mineral acids that result in severe localized corrosion.

Continued on back page……..

These types of microbiologically induced corrosion (MIC) cause what can be substantial metal loss that is focused in a small area, necessitating downtime and expensive repairs or even replacement of piping, towers and heat exchangers.

Fortunately, the problems associated with biofilm formation can be mitigated, and, in many cases, prevented entirely. Routine sweeping of tower basins and decks will help prevent excessive accumulations of dirt, dust and other airborne debris that serve as habitat and sources of nutrients for biofilm-forming bacteria. Properly designed full-flow or side-stream filtration is recommended to aid in this process, particularly in systems that are especially susceptible to airborne contamination.

Finally, and perhaps most importantly, a qualified water treatment professional can prescribe a program of maintenance and chemical treatment to control microbial growth and retard biofilm development. Based on a survey of operating equipment and system water chemistries, along with a site-specific microbiological profile, the treatment specialist will select a program that includes appropriate filtration, if needed, and a suitable dual microbiocide regimen.

An oxidizing biocide such as bromine or chlorine dioxide, alternated with a non-oxidizing product such as isothiazolone, glutaraldehyde or DBNPA, will provide effective control over the growth of most strains of algae and bacteria. A biodispersant or biofilm cleaner may also be recommended as an adjunct to the biocide program to further assure that biofilm development is held in check.

Biofilm can cost a company or facility thousands of dollars per year in excess cooling system repair, maintenance and operating costs. A relatively small amount of money spent on a well-designed treatment program can keep this sticky problem from being a drain on their bottom line.