Biofilms—Mechanisms of Membrane Fouling

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To understand biofilms, we first have to understand what they are and how they form. A biofilm is a conglomerate of microorganisms, such as algae, fungi and/or bacteria, held together, in part, by a sticky substance known as exopolysaccharidei. Bacteria produce exopolysaccharide, or slime, following surface attachment. This slime may be 100 or more times the mass of the bacterial cells and helps to anchor and protect the microorganisms present.

Biofilms may form on virtually any surface and in a variety of environments. After continued growth, they may be visible to the naked eye, such as those unsightly toilet bowl rings, or the unpleasant film on one's teeth in the morning. The individual organisms that make up biofilms, however, are generally too small to be seen with the naked eye, and require special microscopic equipment to be visualized.

An issue in water

Biofilms are a valid concern in industrial water systems as they may foul membranes or other equipment, diminishing the process efficiency and membrane lifetime. In addition to fouling, increased scale and corrosion are further problems related to and accelerated by biofilm formation (see Buckman Laboratories, *If You'd Like to Know More...).* In a biofilm environment, organisms may feed off of other organisms or their metabolic products while being protected from surrounding stresses, such as temperature and pH fluctuations, disinfectants or in creased pressure. Biofilms are especially adept at accumulating in low-flow areas of water distribution systems and may go unnoticed at first, but as they continue to grow, the expanding matrix may impede or completely block flow.

Not all bad

Biofilms aren' t all bad. In fact, they play a vital role in wastewater treatment. Wastewater is often trickled onto rocks covered with biofilms capable of degrading organic wastes. This process is known as biodegradation and also has been used to clean up oil spills, pesticide contamination and ground water contamination withPCE (perchloroethylene; a dry-cleaning agent and common U .S. groundwater contaminant), just to name a few. And, housed in their protective slime layer, biofilm bacteria are ideal tools for bioaccumulation of chemical and metal pollutants (zinc, copper, lead, iron, cadmium, arsenic, uranium, manganese) in contaminated soils and water. Furthermore, biofilms aid in the diges-tive process of animals and, in soil, help to provide essential nutrients to plants.

Public health impact

The extensive network of exopolysaccharide and bacteria continue to attract other microbial communities of algae and protozoa. Pathogenic organisms such as *Legionella, Cryptosporidium, Giardia* and viruses are thought to accumulate in biofilm matrices. Biofilm associated viruses may be resistant to disinfectants and survive 2-to-l 0 times longer than free-floating populations. Biofilm associated bacteria have been reported as being at least 500 times more resistant to microbiocides than their free-floating counterparts. This increased resistance is attributed to the protective polysaccharide coat, since the biofilm bacteria again become susceptible to disinfectants after being separated from this layer.

Biofilms play a role in the rejection of artificial dental and medical pros-theses and in a number of infectious diseases. Not only do biofilms form on teeth but also in the gut, bladder, contact lenses, rocks in streams, heart valves, catheters, water lines and virtually any environment that is exposed to nutrients and moisture. Harold C. Slavkin, director of the National Institute of Dental Research, said the formation of adverse biofilms has become an almost $20 billion health problem for the American people.

Biofilm control

Before one can effectively develop control methods for biofilms, it's important to understand their complex structure and nature in various environments. Biofilms appear to be highly channeled, attracted to air pockets and areas suitable for water and nutrient flow. With moisture, air and nutrients available, as well as to the outside edges of the matrix, diverse microbial populations may survive and proliferate at various depths and not just at the biofilm surface. As excessive material