Biofouling: TEP – a major challenge for water filtration

Biofouling is a major and very expensive problem for the water industry. Biofilm resulting from the growth of microorganisms on reverse osmosis and ultrafiltration membranes is a serious issue in desalination and water treatment plants, requiring a variety of pretreatment strategies to minimise the problem. Tom Berman of the Kinneret Limnological Laboratory describes the latest thinking on the subject.

The generally accepted scenario for the process of aquatic biofilm formation on surfaces runs as follows. Firstly, bacteria from the overlying feed water attach to the surface that may have been ‘preconditioned’ by being rapidly coated with some organic colloidal material from the water. The attached bacteria grow and multiply, fueled by nutrients in the water, and extrude a gooey, gel-like, sticky material called EPS (extracellular polymeric substances) that is largely but by no means exclusively composed of polysaccharides (sugars). This EPS serves as a matrix to attach the growing biofilm to the surface and holds it together. As the biofilm develops, chunks of EPS plus attached bacteria are sloughed off; some of these may stick again to surfaces downstream and form more biofilm. An important point in this scenario is that living, dividing bacteria are required to generate the EPS matrix. It follows therefore that removing the bacteria from the feed water (for example, by filtration) or inactivating them (for example, by strong UV irradiation) should effectively reduce biofilm formation and development.

Biofilm development

Although this scheme of aquatic biofilm development is certainly valid, it is not the whole story. Recent research has shown that microscopic transparent organic particles abundant in most source waters are also important players in biofilm development on membranes and other sensitive surfaces. Since their discovery in the ocean in 1993, the characteristics and ecological importance of these so-called Transparent Exopolymer Particles (TEP) have been extensively studied in both marine and freshwater environments (see Box 1 – What are Transparent Exopolymer Particles?). An article by Berman and Holenberg in Filtration+Separation (May 2005) first introduced TEP to the filtration community. Based on the known characteristics of TEP, especially their extreme stickiness and extensive surface area, Berman and Holenberg proposed that these particles should be important in fouling processes and suggested that reducing the amounts of TEP in source waters by effective filtration would slow down biofilm development.

New research

The important role of TEP in early biofilm formation was shown when the research team found that, in the very early stages of biofilm development on clean surfaces, areas which stained blue with a dye for polysaccharides, i.e. for TEP or EPS, were much more extensive than those covered by attached bacteria (see Box 2 – How TEP

What are Transparent Exopolymer Particles?

As the name implies, Transparent Exopolymer Particles (TEP) are transparent, microscopic organic particles ranging in size from about 0.4 to 100-200 microns. They are found in large numbers in most kinds of source water (seas, lakes, rivers, reservoirs and recycled wastewater). TEP appear in many forms; amorphous blobs, filaments, clumps and sheets, and are sometimes recognisable as debris from broken plankton (see Box 3 – TEP). Similarly to EPS, these particles are mainly composed of polysaccharides although proteins and nucleic acids may also be present. TEP have a large, negatively charged, surface area that makes them very sticky. Many TEP are colonised by bacteria that find them a convenient and a nutritional platform on which to grow. In natural water bodies such as oceans and lakes, TEP have been found to play important roles in the healthy functioning of these ecosystems.
and bacteria are involved in newly developing biofilm. Clearly, the TEP/EPS observed could not have been produced by the small numbers of bacteria that had settled on the surface. Therefore, the source of the blue-staining TEP/EPS on the surface was from TEP in the overlying seawater.

Using an experimental cross flow filtration system with lake water to observe biofilm forming on UF membranes, it was found that about the same area was covered with EPS after 24 hours, irrespective of whether the bacteria in the source water were alive or dead. This indicated that active, live bacteria were not required to form the initial EPS but that the source of this EPS was TEP in the feed water that had stuck to the surface. Also, a significant correlation was found between TEP concentration in lake water and the rate of membrane clogging.

**Planktonic EPS**

Perhaps it is helpful to think of TEP simply as a kind of planktonic (suspended in the water) EPS. Another point to remember is that many of the TEP in the water are already loaded with bacteria and, being composed of organic matter, can provide a convenient, on-the-spot source of nutrition for their passengers. Although not yet

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**How TEP and bacteria are involved in newly developing biofilm**

Microscope images of TEP and bacteria adhering to a glass surface immersed in coastal sea water after 18 hours. T = TEP; B = Bacteria; Scale bar – 10 microns.

Left: Viewed with regular illumination, TEP (or EPS) are the blue patches, Bacteria cells are the isolated rods on the surface.

Right: Same view but with UV-epifluorescent illumination. Here only bacteria show as scattered rods.

Note how much more of the developing biofilm surface is covered by TEP (EPS) than by bacteria. This confirms that the TEP (EPS) must have come from the overlying water and were not extruded by the attached bacteria.

shown experimentally, probably more and more TEP from the feed water continues to stick on the biofilm as it develops.

Our modified version of the process of biofilm development implies that lowering levels of TEP in feed water reaching sensitive surfaces could be an effective means of controlling biofilm. However, TEP is present in considerable numbers in almost all source waters (See Box 3 – TEP) and may prove to be a tough customer to handle.

At the Adom desalination plant in Israel, it was found that although pre-treatment by sand filtration followed by cartridge filtration significantly lowered the Silt Density Index (SDI) and turbidity of water reaching the RO membranes, TEP levels were usually much less affected. Dutch investigators have reported high concentrations of TEP-like material sized between 0.05 and 0.4 microns in both seawater and freshwater and observed that significant amounts of these ‘mini-TEP’ remained even after MF/UF membrane pre-treatment in two wastewater treatment plants.

We are only just beginning to understand the involvement of TEP in aquatic biofilm development. Nevertheless it is already clear that it will be necessary to develop strategies and ‘smart’ filtration media to effectively and economically reduce the amounts of TEP, as well as minimising the numbers of active bacteria in feed water reaching membranes and other sensitive surfaces. If successful, this could prove a winning approach to control the problems of biofilm.

Further reading

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Research Professor (Emeritus) Tom Berman is an aquatic microbiologist at the Kinneret Limnological Laboratory, (Israel Oceanographic and Limnological Research). He has been interested in TEP ever since finding large numbers of these fascinating particles in Lake Kinneret, otherwise known as the Sea of Galilee. A few years ago, he realised that TEP was most likely involved in aquatic biofilm formation.