Bacterial Adhesion to Synthetic Membrane Materials: Theory and Methods

Eric M.V. Hoek ~ Professor, Civil/Environmental Engineering, University of California, Los Angeles, USA

~International Symposium on Membrane Biofouling: Science & Solutions~
28-30 April 2010, Copper Queen Hotel, Bisbee, Arizona, USA

Biofouling of membranes involves a number of processes including: initial (largely reversible) cell attachment; longer-term (largely irreversible) attachment via exopolymer anchoring; replication, communication, and coordination; and sloughing, re-arrangement and secondary adhesion. In this talk, I focus on physicochemical interactions governing initial bacterial cell adhesion – an early, but important stage of the much more complex overall process of biofouling. Initial cell adhesion is predominantly influenced by hydrodynamics, solution chemistry, membrane surface characteristics, and cell surface properties; although, physicochemical surface properties of bacterial cells are dynamic functions of environmental and biological factors. Moreover, adsorption of natural organic matter and chemical cleaning alter membrane surface properties. Hence, in practice clean (or as-produced) membrane properties may only dictate biofouling propensities for very short periods of time.

Many past studies have used parallel plate flow chambers to microscopically observe bacterial adhesion onto impermeable substrates, but such systems do not represent the hydrodynamic conditions in membrane processes. We have developed a series of optical filtration modules that allow direct microscopic observation of bacterial adhesion onto membranes for operating conditions ranging from microfiltration to seawater reverse osmosis. We combine direct observation with rigorous characterization of membranes, bacteria, water chemistry, and hydrodyanmics to formulate a comprehensive understanding of their complex, interrelated roles in initial bacterial adhesion to membranes.

In this presentation, I will review the basic theories, experimental techniques, and our interpretation of the results of bacterial adhesion studies that have been ongoing for many years, highlighting: (a) optimization of hydraulic backflushing for MF/UF membranes, (b) understanding the impacts of salt concentration polarization for bacterial adhesion to NF/RO membranes, and (c) elucidating the roles of classical DLVO and non-DLVO forces in bacterial adhesion to as-produced, fouled, and cleaned membranes. I will also discuss our more recent efforts to extend this laboratory research tool into a practical, early-warning fouling detector for full scale treatment plants.