

## Targeting Biofilms in Translational Research, Device Development, and Industrial Sectors

### *Escherichia coli*

The characterization of membrane biofouling involves evaluating the microbial community, the fouling layer, and the quantification of the EPS matrix. Various assays, microscopic and spectroscopic techniques have been employed to characterize membrane biofouling [ 29 ]. Kerdi et al. [ 30 ] used 3D-optical coherence tomography (OCT) to characterize the intrinsic structure and the mechanical properties of the biofilm developing on ultrafiltration (UF) polyethersulfone membranes without altering their chemical and/or physical properties. Three-dimensional images of the biofilm were obtained with high resolution, enabling the biofilm microstructural morphology analysis. The structural properties were found to be dependent of time as the biofilm continuously evolved, i.e., the biofilm was more elastic in nature at the initial stages of its growth. Still, it then transitioned into a more viscoelastic type as it matured. Benladghem et al. [ 31 ] used surface enhanced Raman spectroscopy (SERS) to identify biofoulants accumulated on spiral-wound reverse osmosis (SWRO) membranes. They also imaged the fouled membranes' topography and the biofilm structures using fluorescence microscopy (FM) and scanning electron microscopy (SEM). The microscopy images showed that both biotic and abiotic deposits were present on the membrane; in addition, SERS showed that the thickness of the fouling layer reached up to 5µm. In another study, Zahid et al. [ 32 ] used thermal analysis (differential scanning calorimetry, DSC), contact angle, SEM, Fourier transform infrared (FTIR) spectroscopy, and the disc diffusion method to characterize cellulose acetate (CA)-sulfonated graphene oxide (SGO)-doped membranes and assess their anti-biofouling properties. The functionalization of CA membranes with SGO was confirmed using FTIR, while the morphology of the doped membranes was studied using SEM. The thermal stability of the doped membranes was investigated using DSC and revealed an increase in thermal stability of CA-SGO membranes upon the addition of SGO. pathogenic bacteria were used in the disc/agar well diffusion test through measurement of inhibition zone. The test results showed that that antibacterial activity of the CA membrane is increased with increased SGO content of SGO. This behavior was attributed to the fact that the surface of CA-SGO-doped membranes had a negative charge from the sulfonic acid and hydroxyl groups of SGO, which led to electrostatic repulsion between the microorganisms and the membrane. Masigol et al. [ 33 ] developed an interesting technique to characterize and identify multi-species biofilms termed polymer surface dissection (PSD). PSD uses targeted and ultraviolet (UV)-responsive polyethylene glycol hydrogels to bind to and detach microorganism aggregates from membranes. The detached aggregates are then exposed to UV light to release aggregates of the desired size for DNA extraction. The efficacy of PSD was demonstrated by identifying the bacterial community structure (aggregate area of 5000-60,000 µm<sup>2</sup>) developed during early-stage biofouling of aerobic wastewater communities over polyvinylidene difluoride (PVDF) membranes. The findings showed that larger aggregates had less bacterial diversity. Moreover, the bacterial community structure shifted from one rich in *Bacteroides* to one with more proteobacteria when the aggregates areas reached the 25,000-45,000 µm<sup>2</sup> size range. The efficiency of bacterial transfer between the membrane surface and the hydrogel still poses an issue for the developed method. The authors proposed using

## P

poly-Llysine (PLL) as a targeting ligand to improve transfer efficiency, as well as the application of external electric fields to enhance transfer efficiency. It is important to note that for EPS matrix characterization, the EPS matrix needs to be extracted first, which can be done using physical methods (e.g., centrifugation, dialysis, filtration, ion exchange, heating), chemical methods (commonly used chemicals include, sodium hydroxide, formaldehyde, ethanol) or a combination of both [ 5 34 ]. Table 1 provides a summary of these techniques and the information that can be obtained from them.

## Reference

[Say Good Night to Insomnia: The Six-Week, Drug-Free Program Developed At Harvard Medical School](#)

[A Cross Section of Nursing Research: Journal Articles for Discussion and Evaluation](#)