Anti-Biofouling Electrospun Surfaces Functionalized by Anti-Quorum Sensing Molecules

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Biofouling is a common source of failure for implanted medical devices, nautical equipment, and water treatment processes. Biofouling involves excessive growth and proliferation of microorganisms that result in biofilm formation on these devices, ultimately damaging output or performance. Biofilms are complex systems that consist of organic compounds, such as carboxylic and amino acids, proteins, carbohydrates, and diatoms. Biofilms consist of protective architectures that provide a safe environment for potentially harmful organisms to thrive. Extracellular polymeric substances (EPS) have been found to coat up to 90 % of biofilms and provide protection against biocides.[1] Severe medical complications can arise from biofilm formation because these complex, shielding ecosystems can render drug interventions less effective or completely ineffective.[2] The U.S. Navy incurs ~$2.1 billion cost annually due to increased drag caused by biofouling on ship hulls.[3-4] In pressure driven water systems, biofilms grow on membranes, decreasing the water output and membrane life. Currently, a wide array of fundamental studies on biofilms and biofouling prevention are being performed to mitigate the issues caused by biofilm formation on engineered systems. Despite these attempts, the issue is far from being eradicated, and some anti-biofouling technologies come with new concerns. For instance, the use of biocides such as copper, silver, and tributyltin has triggered environmental and human health concerns due to their toxicity.[5] Physical surface modifications studied may discourage adherence in one species, while encouraging adherence in the next.[5-6]

The Montana Tech Nanotechnology Laboratory (MTNL) is currently focused on fabricating electrospun, fibrous coatings that provide texture and slow release of molecules that interrupt bacterial signaling. Quorum sensing (QS) is the process used by bacteria to release signaling molecules in response to changing bacterial concentrations. QS plays an important role in biofilm formation. In this work, polymer blends (polycaprolactone-polyethylene glycol) were used to provide slow release of anti-QS molecules (Urolithin A) to prevent biofilm formation on a nanofiltration membrane (Fig 1). The electrospun mesh design provides a hydrophobic coating that will provide physical surface roughness to discourage adherence and is supplemented by slow release of naturally occurring compounds that prevent biofilm formation. Performance of the anti-biofouling coatings will be evaluated visually using confocal microscopy (biovolume, Fig 2) and scanning electron microscopy, and nanofiltration efficiency (water output, flux) will be determined using a bench-scale nanofiltration system (Fig 3).

[1] Silva, E. R. *et al. Sci. Total Environ.* 650, 2499–2511 (2019), [2] Hughes, G., *et al., Br. J. Pharmacol*. 174, 2237-2246 (2017), [3] Evans, S. M. *et al. Mar. Pollut. Bull.* 30, 14–21 (1995), [4] Schultz, M. P. *et al. Biofouling* 27, 87–98 (2011), [5] Nwuzor, I. C. *et al. Saf. Extrem. Environ.* 3, 9–25 (2021), [6] N., V. *et al. Indian J. Geo-Marine Sci.* 43, 2136–2146 (2014).

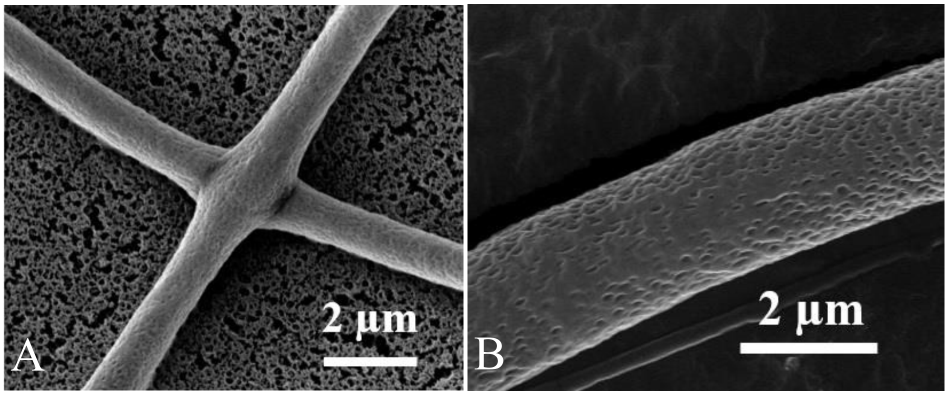

Fig. 1. ***A*** *Electrospun PCL-PEG fibers after being exposed to an aqueous environment. The blend of hydrophobic and hydrophilic polymers provided slow release of anti-QS molecules while maintaining structure.* ***B*** *Electrospun PCL-PEG fibers at higher magnification, showing the pores formed at the fiber surface following exposure to an aqueous system. The pores are thought to form where PEG dissolved in water, leaving behind the PCL fiber.*

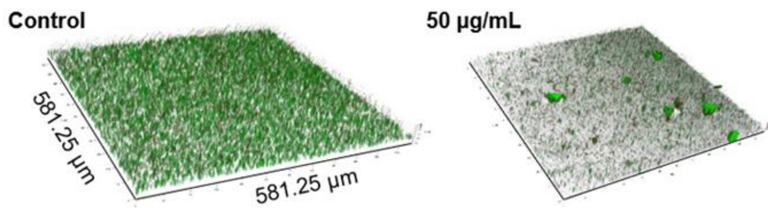

Fig. 2. Biovolumes calculated following no treatment (control) vs treatment with Urolithin A (50 µg/mL). The anti-QS molecules prevented biofilm formation in liquid culture. Future work will provide these molecules through slow release from electrospun fibers.

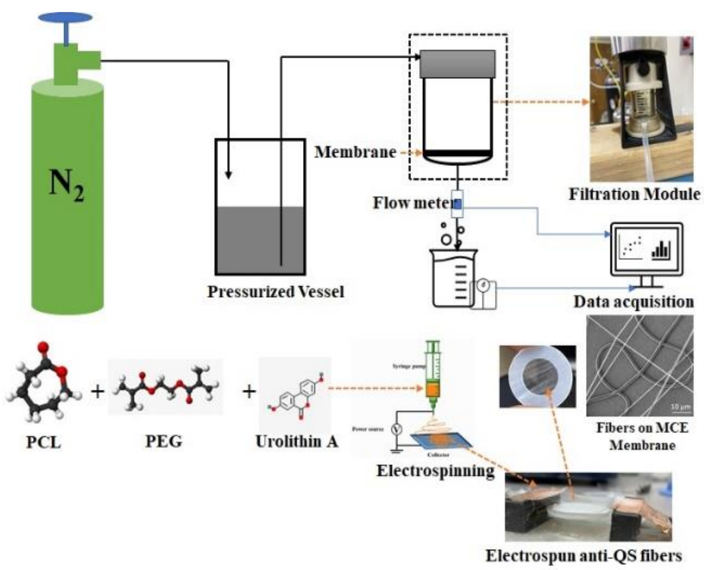

Fig. 3. Nanofiltration hardware setup used to monitor water output efficiencies and biofilm formation on nanofilters functionalized with electrospun anti-QS layers.