Extracellular Polymeric Substances (EPS) Attribute to Biofouling of Anaerobic Membrane Bioreactor: Adhesion and Viscoelastic Properties

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Abstract : Introduction: Membrane fouling is the bottleneck for the anaerobic membrane bioreactor (AnMBR) robust continuous operation, primarily caused by the mixed liquor suspended solids (MLSS) characteristics formed by aggregated flocs and a scaffold of microbial self-produced extracellular polymeric substances (EPS), which dictates the flocs integrity. Accordingly, the adhesion of EPS to the membrane surface versus their role in forming firm, elastic, and mechanically stable flocs under the reactor's hydraulic shear is critical for minimizing interactions between EPS and colloids originating from the MLSS flocs with the membrane. This study aims to gain insight and investigate the effect of MLSS flocs properties, EPS adhesion and viscoelasticity, viscoelastic properties of the sludge, and membrane fouling propensity. Experimental: As a working hypothesis, to alter the aforementioned flocs' and EPS's properties, the addition of either coagulant or surfactant was carried out during the AnMBR operation. In the AnMBR, two flat-sheet 300 kDa pore size polyether sulfone (PES) membranes with a total filtration area of 352 cm2 were immersed in the AnMBR system treating municipal wastewater of Midreshet Ben-Gurion village at the Negev highlands, Israel. The system temperature, pH, biogas recirculation, and hydraulic retention time were regulated. TMP fluctuations during a 30-day experiment were recorded under three operating conditions: Baseline (without the addition of coagulating or dispersing agent), coagulant addition ($FeCl_3$), and surfactant addition (sodium dodecyl sulfate). At the end of each experiment, EPS were extracted from the MLSS and from the fouled membrane, characterized for their protein, polysaccharides, and DOC contents, and correlated with the fouling tendency of the submerged UF membrane. The EPS adherence and viscoelastic properties were revealed using QCM-D via the PES-coated gold sensor used as a membrane-mimicking surface providing a detailed real-time EPS adhesion. The associated shifts in the resonance frequency and dissipation at different overtones were further modeled using the Voigt-based viscoelastic model (using Dfind software, Q-Sense Biolin Scientific) in which the thickness, shear modulus, and shear viscosity values of the adsorbed EPS layers on the PES coated sensor were calculated. Results and discussion: The observations obtained from the QCM-D analysis indicate a greater decrease in the frequency shift for the elevated membrane fouling scenarios, likely due to an observed decrease in the calculated shear viscosity and shear modulus of the EPS adsorbed layer, coupled with an increase in EPS layer hydrated thickness and fluidity ($\Delta D/\Delta f$ slopes). Further analysis is being conducted for the three major operating conditions-analyzing their effects on sludge rheology, dewaterability (capillary suction time-CST) and settle ability (SVI). The biofouling layer is further characterized microscopically using a confocal laser scanning microscope (CLSM) and scanning electron microscope (SEM), for analyzing the consistency of the development of the biofouling layer with sludge characteristics, i.e., thicker biofouling layer on the membrane surface when operated with surfactant addition, due to flocs with reduced integrity and availability of EPS/colloids to the membrane. Conversely, a thinner layer when operated with coagulant compared to the baseline experiment, due to elevation in flocs integrity.

Keywords : viscoelasticity, biofouling, viscoelastic, AnMBR, EPS, elocintegrity
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