Impact of permeate flux on biofilm development in spiral wound membrane systems

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1. Introduction

In membrane based water treatment, biofilm formation on the membrane surface is a major problem. Current physical or chemical cleaning strategies are not successful in biofilm removal in most of the cases. A better understanding on the biofilm morphology and mechanical properties may lead to more effective biofilm control strategies.

The objective of this study was to investigate the morphological and mechanical changes of the biofilms under different water fluxes (through the biofilm) in membrane systems.

2. Methods

A lab-scale forward osmosis membrane system was used for the experimental evaluation of biofilm development on the membrane surface at various permeation fluxes. Two gear pumps circulated in closed loop the feed and draw solutions at similar cross-flow velocities. The pumps were connected to two reservoirs, one for the feed solution and one for the draw solution. The feed solution reservoir was placed on a digital scale connected to a computer. The water flux through the membrane was calculated from the change in weight of the feed solution reservoir. All experiments were performed at 20 °C.

Forward osmosis membrane with a thickness of ~50 µm was used for the experiments. In all cases, the membrane active layer faced the feed solution while the support layer was in contact with the draw solution.

The membrane was placed into a custom-made flow cell from, with an active membrane area of 20 cm^2. The flow cell was designed to allow operation without and with the presence of spacer in the feed and draw channels. The feed and draw channels height were the same and could fit 34 mil (863 µm) thick spacers. The biofouling experiments were run in a repeated batch mode. Each batch cycle was interrupted after 24 h of operation and the feed and draw solutions were replaced by fresh solutions, then the next cycle was started. To ensure biofilm formation in the feed channel, the feed solution consisted of sodium acetate, sodium nitrate and sodium dihydrogen orthophosphate in the mass ratio for C:N:P of 100:20:10 dissolved in tap water.

The impact of permeate flux change on biofilm thickness, structure and rigidity was investigated *in-situ* and non-destructively with Optical Coherence Tomography (OCT). In situ imaging of the feed channel surface of the membrane was performed using a spectral domain optical coherence tomograph (Thorlabs Ganymede OCT System). The OCT was fitted with a 5 × telecentric scan lens (Thorlabs LSM03BB) which provides a maximum scan area of 100 mm^2. The OCT engine was configured to provide high-resolution images with a sensitivity of 106 dB at 1.25 kHz A-scan rate.

Volumetric images were created using the maximum intensity profile algorithm included in the instrument software (Thorlabs SD-OCT system software version 3.2.1).

3. Results and Discussion

Figure 1 shows the OCT scans of the membrane, with a biofilm present on the membrane surface. The scans for the pre-compaction phase, taken at a lower permeate flux of ~20 L·m-2·h-1, showed a smooth, fluffy and mushroom-like biofilm structure. The biofilms on a higher flux ~60 L·m-2·h-1, was compressed to 49% compared to the biofilm measured under low flux conditions. The impact of biofilm accumulation on membrane performance is influenced by membrane module configuration, membrane plant design and operational aspects. A membrane system operated at a high or variable permeate flux may suffer from a compact biofilm formation, causing a high hydraulic resistance (high energy use and low permeate production). If the membrane system is operated at a low and constant permeate flux, the impact of biomass accumulating on membrane performance can be significantly lower.

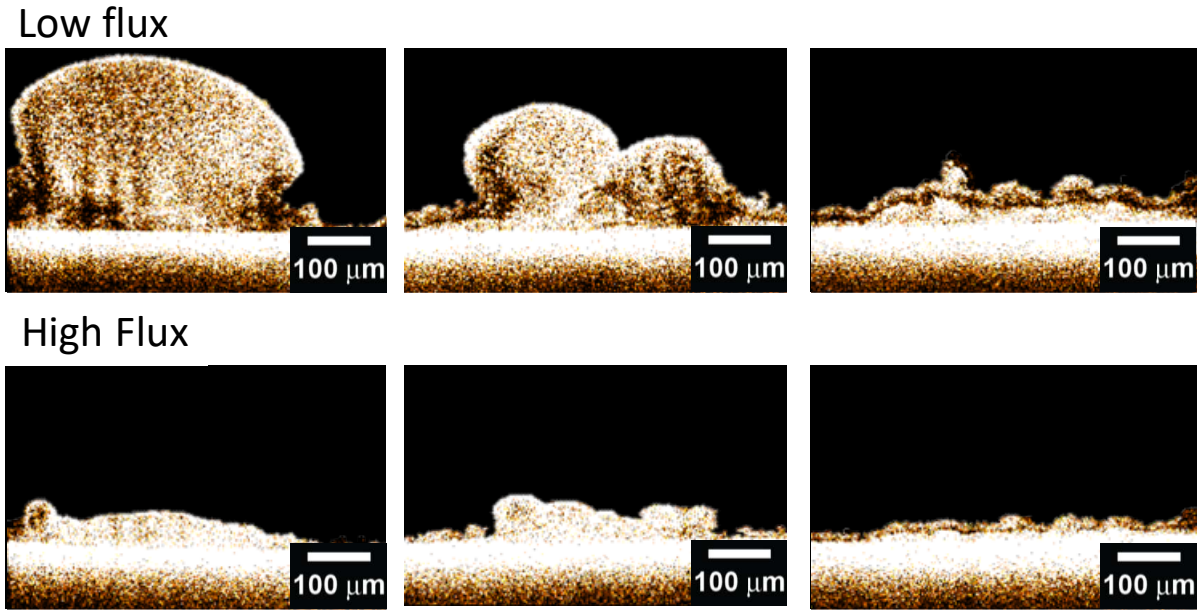


Figure 1. OCT images of biofilms formed at different (low and high) permeate flux.

4. Conclusions

In situ biofilm thickness measurements using OCT were used to analyse the impact of permeate flux on biofilm formation in membrane systems Based on the results (i) an increase in water permeate flux resulted in more compact biofilm, decreasing the biofilm thickness and increasing the hydraulic biofilm resistance, (ii) OCT measurements provided useful structural information (i.e. thickness) on biofilms developed in membrane systems under various operating conditions.

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