Impact of sludge flocs, colloidal particles and EPS on membrane fouling in MBR systems

Morten L. Christensen*, Mads K. Jørgensen, Thomas V. Bugge, Poul Larsen, Marta Nierychlo, Rikke Justesen, Natalie B. Sørensen, Per H. Nielsen

*Department of Chemistry and Bioscience, Aalborg University, Frederik Bajers Vej 7H, 9220 Aalborg Øst, Denmark (*mlc@bio.aau.dk)*

Introduction

Membrane bioreactors (MBR) is an effective technology for treating wastewater due to high effluent quality and low footprint. However, the technology is limited by accumulation of sludge compounds on the membrane (fouling). Sludge contains flocs, single cells, filaments, soluble microbial products (SMP) and ions. Especially, SMP and single cells are known to foul the membrane, whereas flocs seems to improve the permeate flux. The hypothesis in this work is that flocs remove SMP and single cells from the membrane surface due to scouring effect. This improves the permeate flux. Thus, high concentration of large compact flocs are required to ensure high flux.

Theory

Rejected particles concentrate near the membrane surface and foul the membrane. Air scouring is often used to remove these particles, but it is difficult due to the liquid film (≈10 μm) at the membrane surface. Small particles diffuse back to the feed due to the high diffusion coefficient (green line, fig 1); i.e. the extension of the concentration polarization layer exceeds the thickness of the liquid film. Large particles erodes away from the surface because the particle size exceeds the thickness of the liquid film. However, SMP and single cells are difficult to remove (Fig 1). Sludge flocs are large and erodes at the surface. It is expected that they thereby remove foulants and increase flux.

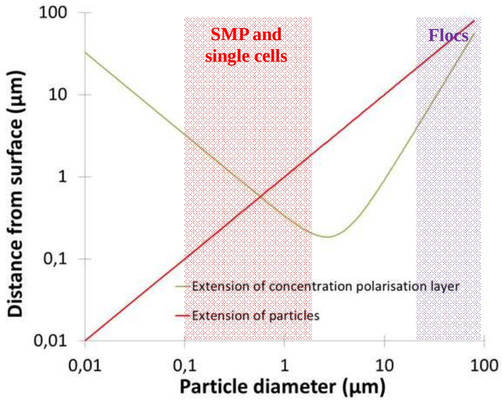


Figure 1: Extension of concentration polarization layer and particles from the surface of the membrane
The extension of the concentration polarization layer was done assuming that concentration polarization modulus was 10 and the permeate flux was 10 LMH.

Sludge fractionation

Sludge was sampled from a pilot plant MBR (SS = 9.5 g L^{-1}, pH = 7.3, Λ = 1,3 mS cm^{-1}) and centrifuged at 880g for 2 min. to remove sludge flocs (Fig. 2). The flocs were resuspended in tap water. Floc suspension or supernatant (5 L) was then filtered through 84 cm^2 flat sheet PVDF membrane, nominal pore size 0.2 μm (Fig. 3). The membrane was air scoured (0.5 L min^{-1})

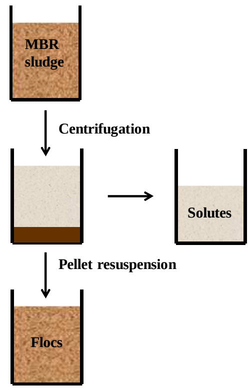


Figure 2: Sludge fractionation method

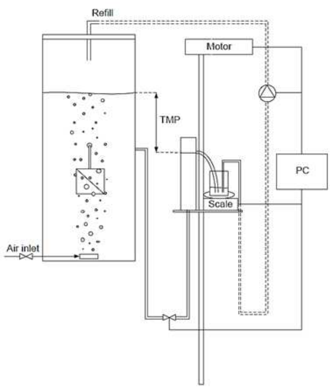


Figure 3: Lab scale filtration setup

Mathematical model

The permeate flux was calculated using the resistance-in-series model assuming that fouling resistance increases proportional with mass of material deposed on the membrane, and the resistance increases proportional with pressure

$$J = \frac{P}{\mu(R_m + \alpha\omega)}, \qquad \alpha = \alpha_0 + kP, \qquad \frac{d\omega}{dt} = JC_b - J_{lim}C_b$$

J: Permeate flux; *P*: Transmembrane pressure; R_m: Membrane resistance; α: Specific resistance; α_0: Specific resistance zero pressure *k*: compressibility; ω: Deposed material per area; C_b: Foulant concentration in bulk; J_{lim}: Limited flux.

Results

The sludge (red) and the supernatant (blue) was filtered at different pressures. The highest flux was observed for the sludge suspension (≈ 80 LMH) i.e. flocs has a positive effect on the permeate flux. Additional experiments have shown that the flux of the supernatant could be increased by adding resuspended flocs and the flux increase with floc concentration.

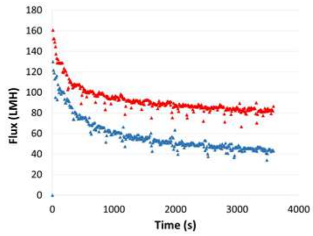


Figure 4: Filtration of MBR sludge (red points) and supernatant (blue points) at 11 kPa

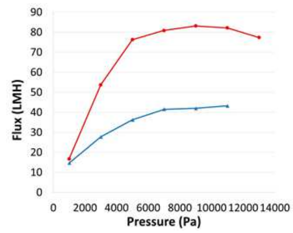
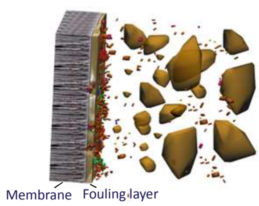


Figure 5: The steady state flux after filtration of MBR sludge (red points) and supernatant (blue points)



Membrane fouls due to single cells and SMP by forming a 10-20 μm tight compressible fouling layer (α_0 = 4.3 mkg^{-1}, k = 1.3·10^9 m kg^{-1} Pa^{-1}. Sludge flocs reduce the thickness and/or the resistance of the layer. Good floc properties are obtained by ensuring low constant conductivity, high water hardness, and effective aeration.

Conclusion

The concentration of free cells and SMP should be kept low in MBR systems because the compounds fouls the membranes. Good floc properties reduce the concentration of free cells and SMP. Further, high concentration of compact flocs reduce membrane fouling due to membrane scouring and formation of more loose fouling layers.

Acknowledgements

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