Hydraulic resistance of membrane biofilms: effect of extracellular polymeric substances

Keywords: drinking water production, membrane filtration, biofilm, Extracellular Polymeric Substances, hydraulic resistance

Background
Bacteria inevitably colonize membrane filtration systems to form biofilms (van Loosdrecht et al. 2012). The formation of biofilms on membrane surfaces reduces permeate flux due to the increased hydraulic resistance. But practical experience indicates that avoiding the formation of biofilms is almost impossible. Eawag has thus developed a new paradigm for the operation of membrane systems, which consists in taking advantage of biofilms formed on membrane surfaces. The biofilm present controls both the quantity and quality of the permeate. In such a system, more than 80% of the hydraulic resistance is due to the biofilm (Derlon et al. 2016).

The extracellular polymeric matrix (EPS) can account for over 90% of biofilm mass (Flemming and Wingender 2010) and consist of polysaccharides (PS), extracellular deoxyribonucleic acids (eDNA), proteins, amyloids, and amphiphilic surfactants. The hydraulic resistance of a biofilm directly correlates with its PS and eDNA content (Desmond et al. 2018), but the causality and nature of this relationship has yet to be demonstrated. This project will increase our fundamental understanding of the role of hydrodynamic stresses in determining the composition and mechanical properties of the biofilm EPS matrix. The great potential of biofilm-membrane composites is successfully applied in various water treatment systems developed by Eawag, e.g., recycling of grey waters in the Water Wall. But a broader application requires further advances in our fundamental understanding of the mechanisms governing biofilm hydraulic resistance.

Objectives of the suggested topic
The main objective of the proposed master thesis is thus to identify the causality link between the EPS composition (especially polysaccharides and eDNA) and the hydraulic resistance of membrane biofilms. Usually, the main challenge in determining the causality of this relationship results from the complex composition of the EPS matrix of natural biofilms. We thus proposed to use Pseudomonas aeruginosa, a model organism, to study the biofilm formation on membrane surface and to understand its effect on the filtration performances.

The use of model organisms allows the formation of model biofilms with a controlled composition, a crucial resource in determining the link between chemical composition and mechanical properties of the biofilm.

This master thesis especially aims at addressing the two following questions:
• How do the different components of the EPS matrix (PS, eDNA) influence the hydraulic resistance of membrane biofilms?
• How does the absolute pressure of the feed water influence the secretion of EPS and ultimately the hydraulic resistance of the biofilm?

Two main experiments will be conducted to identify the role of PS/eDNA (experiment #1) and of the feed water pressure (experiment #2) on the hydraulic resistance of biofilms. Pure-culture and (complex) river water biofilms will be grown in membrane fouling simulators. Advanced chemical, molecular and imaging tools will be used to visualize and characterize the biofilms.

Specific information / Requirements
Interests in drinking water production, membrane filtration technologies. Interests in biofilm science (biofilm lifecycle, biofilm mechanics) and will to work with the opportunistic human pathogen Pseudomonas aeruginosa (Safety level 2).
This master thesis is a joint work between the groundwater and hydromechanics lab of ETHZ (Dr. E. Secchi, Prof. R. Stocker) and Eawag (Dr. N. Derlon, Prof. E. Morgenroth). The work will mainly be conducted at ETHZ.

Advisors and Supervisors
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References

