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[P2.156] Understanding the mechanisms of biofouling on nanofiltration membranes: Effect of the biofilm structure on solute removal

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Nanofiltration membranes are commonly used in water treatment for water softening and removal of organic matter and small trace contaminants, such as pesticides [1]. However, the occurrence of biofouling on these membranes [2, 3] is a major drawback as it impacts on the water quality and amount of product obtained. The accumulation of biofilm on the membrane surface (Fig. 1) and spacer [4] causes an increase of pressure drop along the membrane module [5, 6], which has obvious implications for energy consumption. Furthermore, when biofilm grows on the membrane surface, the permeate flux and the retention of salts and organic solutes decreases with time and damage of the membrane structure might occur [7, 8]. Due to the ubiquitous presence of microorganisms in the environment and consequently of biofouling on nanofiltration membrane systems, it is important to understand what impacts its formation and what mechanisms are involved.

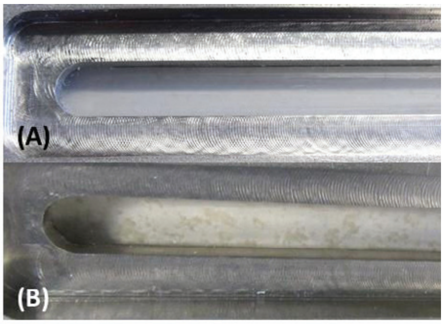

Fig. 1 – NF 90 membrane fouled in the MFS system with *P. fluorescens* **(A)** before inoculation and **(B)** 4 days after inoculation

It has been well established that the mechanism that causes flux decline and decreased retention of salts and organic solutes in the presence of colloidal fouling or biofouling is enhanced osmotic pressure [9-12]. However, there is a clear gap in understanding the impact of the biofilm structural characteristics such as thickness, density, number of cells, EPS characteristics, etc. with the nanofiltration performance when removing salts and organic solutes. The biofilm characteristics will have an impact on the salt or organic solute transport through the fouling layer. This will consequently impact on the concentration polarisation and hence, affect the cake or biofilm enhanced osmotic pressure.

Biofouling is caused in most cases by heterotrophic organisms that form a biofilm with dissolved organic material as a carbon source. Biofilms are dynamic, often structurally complex communities of surface-adhering microorganisms that are embedded within an extracellular polymeric matrix [13, 14].

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This biofilm is very responsive to the environment that surrounds it and as a result, the biofilm structure can vary significantly. For example, the presence of magnesium or calcium in the water influences the biofilm characteristics [15, 16], where, for example, complexation with the divalent cations can occur causing swelling of the biofilm [17]. High ionic strength can cause charge shielding which reduces charge repulsion between the polysaccharide molecules and enhances the adsorption of these [18].

The other parameter affecting the biofilm structure is the shear force, *i.e.* the hydrodynamic conditions, where, for example, at higher flow velocities patches of ripples and elongated streamers which oscillate in the flow can be formed and the higher the velocity the thinner and the denser the biofilm is [19-21].

The characteristics of the surface where the biofilm adheres, in this case the nanofiltration membrane, has an impact in the initial adhesion of cells, and possibly on the structure of a mature biofilm. In general, the rougher and the more hydrophobic the membrane is, the more cells will adhere to the surface [22-24].

Finally, higher feed concentrations of nutrients will enhance biofilm growth [5, 6].

All of these variables which are at play in nanofiltration processes for water treatment will impact the biofilm structure and hence the performance of the membrane. We have therefore undertaken a rational investigation of the link between the biofilm structure and the nanofiltration membrane removal efficiency of dissolved salts and organic solutes, as well as permeate flux. The experiments were carried out under aseptic operation and under highly defined and controlled physico-chemical conditions in a cross-flow system with an MFS cell (Membrane Fouling Simulator Cell [25]) (Fig.2).

The MFS cell has a channel height of 0.8 mm in order to accommodate a feed spacer if required, a width of 4 cm and a length of 25.5 cm. The cell is fed by a P200 diaphragm pump (Hydra-Cell) and is therefore able to operate at pressures up to 15 bar, which are typical pressures used in nanofiltration processes for water treatment.

A pure culture of the bacterial strain *Pseudomonas fluorescens* and several nanofiltration membranes from Dow Filmtec, such as the BW30, the NF90 and the NF270 membranes were used in the cross-flow system. A synthetic raw water medium with a carbon source in the form of sodium citrate [9] was recirculated in the membrane system to sustain bacterial growth.

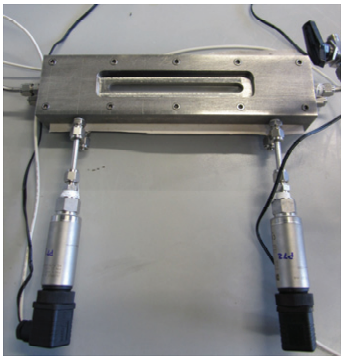

Fig. 2 – MFS cross-flow cell used in the biofouling study

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