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Biofouling patterns in spacer-filled channels: high-resolution imaging for characterization of heterogeneous biofilms

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ABSTRACT

Biofilms develop in heterogeneous patterns at a μm scale up to a cm scale, and patterns become more pronounced when biofilms develop under complex hydrodynamic flow regimes. Spatially heterogeneous biofilms are especially known in spiral wound reverse osmosis (RO) and nanofiltration (NF) membrane filtration systems used for desalination and wastewater reuse to produce high quality (drinking) water. These spiral wound membrane modules contain mesh-like spacer structures used to create an intermembrane space and improve water mixing. Spacers create inhomogeneous water flow patterns resulting in zones favouring biofilm growth, possibly leading to biofouling thus hampering water production. Oxygen sensing planar optodes were used to visualize variations in oxygen decrease rates (ODR). ODR is an indication of biofilm activity. In this study, ODR images of multiple repetitive spacer areas in a membrane fouling simulator were averaged to produce high resolution, low noise ODR images. Averaging 40 individual spacer areas improved the ODR distribution image significantly and allowed comparison of biofilm patterning over a spacer structure at different positions in an RO filter. This method clearly showed that most active biofilm accumulated on and in direct vicinity of the spacer. The averaging method was also used to calculate the deviation of ODR patterning from individual spacer areas to the average ODR pattern, proposing a new approach to determine biofilm spatial heterogeneity. This study showed that the averaging method can be applied and that the improved, averaged ODR images can be used as an analytical, in-situ, non-destructive method to assess and quantify the effect of membrane installation operational parameters or different spacer geometries on biofilm development in spiral wound membrane systems characterized by complex hydrodynamic conditions.

Keywords: Desalination; Biofouling; Sensor; Non-destructive; Feed spacer; Spiral wound

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