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Quantitative measurement and visualization of biofilm O_2 consumption rates inmembrane filtration systems

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There is a strong need for techniques enabling direct assessment of biological activity of biofouling in membrane filtration systems. Here we present a new quantitative and non-destructive method for mapping O_2 dynamics in biofilms during biofouling studies in membrane fouling simulators (MFS). Transparent planar O_2 optodes in combination with a luminescence lifetime imaging system were used to map the two-dimensional distribution of O_2 concentrations and consumption rates inside the MFS. The O_2 distribution was indicative for biofilm development. Biofilm activity was characterized by imaging of O_2 consumption rates, where low and high activity areas could be clearly distinguished. The spatial development of O_2 consumption rates, flow channels and stagnant areas could be determined (Figures 1 and 2). This can be used for studies on concentration polarization, i.e. salt accumulation at the membrane surface resulting in increased salt passage and reduced water flux. The new optode-based O_2 imaging technique applied to MFS allows non-destructive and spatially resolved quantitative biological activity measurements for on-site biofouling diagnosis and laboratory studies. The following set of complementary tools is now available to study development and control of biofouling in membrane systems: (i) MFS, (ii) sensitive pressure drop measurement, (iii) magnetic resonance imaging, (iv) numerical modelling, and (v) biological activity measurement based on O_2 imaging methodology.

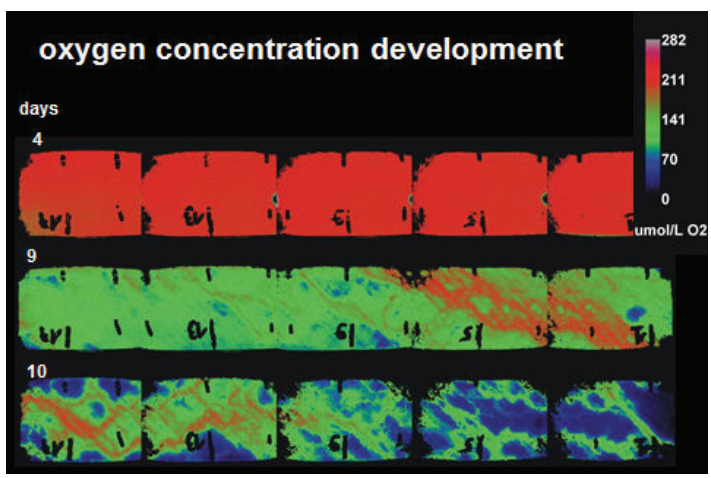

Figure 1: Spatio-temporal distribution of O_2 concentration (µmol O_2 /L) imaged over the monitor length at the optode surface, i.e. the base of the fouling layer. The figure shows the development of low O_2 concentration regions and flow channelling over time. The flow direction is from left to right.

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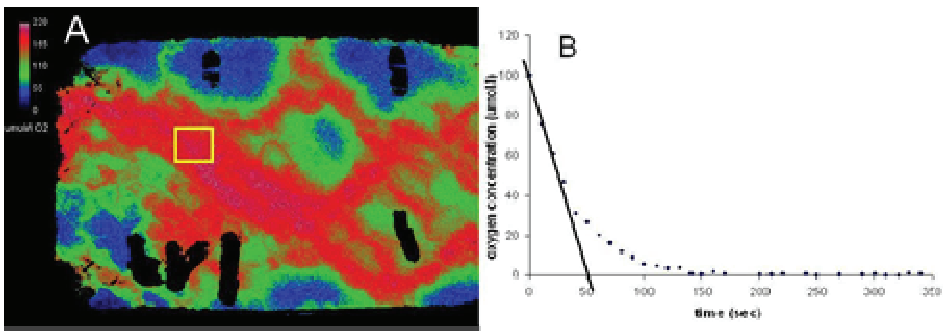

Figure 2. Procedure to determine O_2 consumption rates in the MFS. Oxygen images were taken every 10 s after the flow was stopped. An area of interest (AOI) was selected on the initial oxygen image (A) and the O_2 depletion over time was determined for the AOI (B). The O_2 consumption rate for particular AOIs was calculated from the initial slope of the O_2 depletion curve.

Keywords: biofouling, non-destructive biofouling diagnosis, biological activity measurement, concentration polarization