Fast ultrafiltration characterization by compressed sensing MRI

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Introduction: Ultrafiltrations enable the production of germ and bacteria free drinking water. During filtration, fouling (accumulation of matter on the membrane wall) reduces the filtration efficiency, which means that the membrane has to be backwashed with high energy costs. Since the investigated membrane is filtrated from the inside to the outside, it is difficult to characterize the filtration process optically. It is still unknown if the feed channels of multichannel membranes are filtrated evenly or if there are some differences. MRI can be used as a tool to answer this question and to quantify the performance of the single feed channels. Fast MRI measurements are necessary because the filtration process is highly time-dependent. Therefore, compressed sensing MRI methods are explored.

Methods: Ultrafiltrations were characterized by compressed sensing (CS) MRI methods. Sodium alginate was used as model for extracellular polymeric substances (EPS), which are discussed as the main cause of fouling in waste water treatment. The fouling mechanism can be changed by adding $CaCl_2$ to the aqueous alginate solution. As a result the fouling layer behaves like a gel instead of a concentration polarization. In order to achieve a better T_2-contrast between fouling layer and feed solution, the superparamagnetic magnetite alginate is used as contrast agent. CS MR intensity and velocity images were measured during filtration and reconstructed with a l_1 non-linear conjugate gradient method [1].

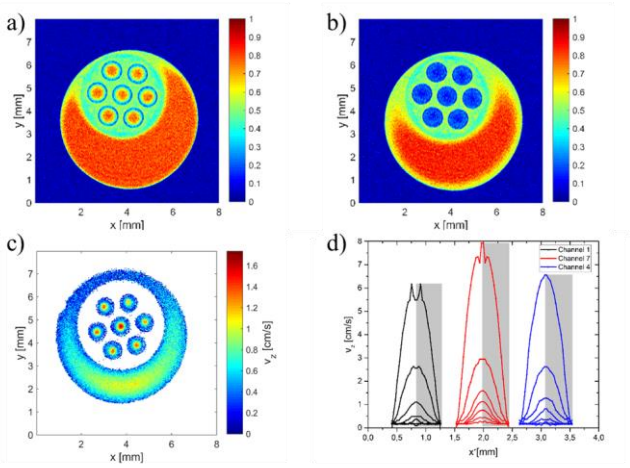

Fig. 1: a) Intensity image of a multichannel membrane at the beginning of the filtration: no deposits in the feed channels. b) after 50 min of alginate filtration the deposits appear with low intensities c) velocity image during filtration. d) flow profiles in the different feed channels were extracted from the velocity images [2].

Results and discussion: Intensity and velocity images were measured during the filtration of alginate (aqueous solution). Fouling layer and flow fields were measured and analyzed. The outer channels of the multichannel membrane perform evenly except for the channel in the center. The velocities and volume flows are slightly higher. The Poiseuille equation describes the data well for the filtration with Ca^{2+}. The flow profiles for the filtration without Ca^{2+} deviate from the Poiseuille profile due to the concentration polarization.

Conclusion: Ultrafiltrations were characterized by CS MR intensity and velocity measurements. Different fouling mechanisms were identified and analyzed.

References:

[1] M. Lustig, Compressed Sensing MRI Resources, Software (2016).
[2] S. Schuhmann et al., J. Membrane Sci. (2019), 570, 472.