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Fundamental **r**esearch to **e**xploit hydrodynamic **e**ffects to reduce membrane fouling by introducing special arrangements of novel feed **space**r geometries in combination with non-regular membrane surface-pattern (**FreeSpace**)

Reverse osmosis and nanofiltration membranes are well-known for their high selectivity towards salts, micro-pollutants, and other emerging contaminants, allowing effective treatment of industrial and municipal effluents, in addition to desalination of brackish water and seawater. Nevertheless, membrane (and module) fouling is a fundamental limitation. Former research has been focused on the development of spiral-wound membrane (SWM) modules, the most frequently employed membrane configuration in RO/NF installations. Typically, SWM modules comprise thin-film composite (TFC) membrane sheets (envelopes), a permeate tube, and feed and permeate spacers. Feed spacers offer inter-membrane spacing; hence they create a flow channel between two adjacent membrane sheets, aiming at establishing proper fluid mixing, mass transfer, and shear stress, which should mitigate concentration polarization and scaling. Nevertheless, they are also found to cause certain localized regions with poor fluid mixing (and low shear stress) along the feed-retentate channel, where particulate fouling and biofouling often occur Biofilm growth is revealed to occur mostly on feed spacer intersections (close to module inlet) causing feed flow distortion that can eventually result in flow clogging, significant increase of axial pressure drop, limitation of overall module performance, and increased energy requirements.

Surface-patterned membranes (i.e., polymeric membranes exhibiting certain regular micro- or nanometer pattern on the active side) have been introduced as a promising approach to overcome typical limitations of feed spacers in SWM modules and promote performance of TFC membranes in water treatment and desalination. ElSherbiny et al. successfully developed surface-patterned TFC membranes for water desalination[1-4]. Chair of Mechanical Process Engineering and Water Technology has developed expertise in preparation and testing of surface-patterned TFC membranes[5,6]. Lab-scale experiments have shown that topographical membrane surface modification can modify fluid characteristics and particle deposition behavior in spacer-free feed-retentate channels. Nevertheless, to the best of our knowledge, neither theoretical (simulation) nor experimental studies have investigated so far fluid characteristics, particle deposition mechanisms, and/or performance and fouling behavior for surface-patterned TFC membrane-feed spacer assemblies.

FreeSpace, research project funded by DFG, aims at exploitation of synergetic influences of surface patterning and feed spacer design can potentially promote hydrodynamic drag, shear stress, and fluid mixing on membrane surface (vicinity) and feed spacer structures. This can essentially mitigate adhesion of foulants, reduce concentration polarization, and thus, boost the critical flux and module productivity. Moreover, membrane surface patterns can be tailor-designed for certain feed spacer geometries, to address biofouling and pressure drop issues at particular module parts (that conventional SWM models are suffering from), if fluid characteristics and spatial foulants distribution in surface-patterned membrane-feed spacer assemblies are reliably characterized and simulated.

Within the framework of **FreeSpace** research project, Chair of Mechanical Process Engineering and Water Technology in University of Duisburg-Essen will collaborate with Chair of Urban Water Systems Engineering in Technical University of Munich to investigate fundamental design and operational aspects determining the overall module performance towards an innovative development approach. Using such approach, membrane surface topography can be specifically designed relative to feed spacer geometry, based on our knowledge of spatial foulant distribution on feed spacer structures at certain operating conditions. Ultimately, this can result in a new generation of tailor-designed non-regular surface-patterned membrane-feed spacer assemblies exhibiting superior antifouling performance.

References

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