Modeling fouling of RO/NF membrane devices

Cristian Picioreanu
Department of Biotechnology, Delft University of Technology, The Netherlands

Reverse osmosis (RO) and nanofiltration (NF) membrane systems are an essential component in worldwide treatment plants for drinking and industrial water production, efficient in removing salts from various types of feed water. The main factor limiting the efficiency and life-time of such processes is their fouling, either by salt precipitation (scaling), colloid and organic deposits, or due to microbial action and biofilm formation (biofouling).

Our understanding of fouling potential in membrane systems can be improved by using mathematical (numerical) models. Our group gradually developed computational approaches integrating the main physical, chemical and biological processes affecting membrane fouling in RO/NF devices. Hydrodynamics in complex three-dimensional domains is needed to describe intricate flow patterns that determine the solute and particle transport, but also to calculate axial and trans-membrane pressure drop, and permeate fluxes. Solute transport by diffusion, convection and ion migration is coupled with several reactions to describe not only the concentration polarization and precipitation of salts, but also the availability of nutrients that cause microbial growth and biofouling. These are coupled with models for crystal formation (nucleation and growth) and of biofilm development (attachment, growth and detachment) on membranes and spacer.

The micro-scale models can explain experimental observations on biofilm and crystal formation, on particle deposition patterns and also describe how these contribute to the decline in performance of spiral-wound RO membrane devices. The mechanistic modeling approach allows the study of the complex interactions in these systems in a systematic manner. It may therefore be useful for improving feed spacer design and to study operational conditions for minimum scaling and biofouling of RO/NF membrane devices.