RESEARCH BRIEF
Start Date: Oct 1 2021 | Duration: 24 months

NAWI National Alliance for Water Innovation

CFD modeling and operando measurements of multiscale heat and mass transfer for membrane module customization

Meagan Mauter | Stanford University

mauter@stanford.edu

Challenge

The reverse osmosis (RO) module is the heart of the RO process: it is a complex, spiral-wound set of membranes and spacers that allow fresh water to permeate through the membrane while rejecting concentrated brine. Optimizing RO modules presents a challenge because improving some aspects of the design under one condition can lead to reduced performance under other conditions. The development of cost-effective, tailored optimization and fabrication methods are critical for enabling the industrial application of new membrane processes for treatment of high salinity brines.

Research Approach

Recent breakthroughs in computational fluid dynamics (CFD) combined with innovations in 3D printing technology may enable a major breakthrough in the design of spiral-wound RO modules. This project will use X-ray techniques to directly measure velocity and concentration gradients in complex membrane module flow channels. These measurements will be used to validate advanced CFD models of RO, Osmotically Assisted Reverse Osmosis (OARO), and Membrane Distillation. The validated CFD models will inform the design of tailored 3D printed spacers geometries that maximize mass and heat transport rates throughout the module for specific feed chemistries and operating conditions (including non-steady state operation).

Impact

Coupling CFD directed flow velocity optimization with innovative manufacturing methods in an industrially scalable workflow has the potential to substantially reduce costs, improve energy efficiency, and reduce the risk of mineral scaling on membrane surfaces. These cost reductions could facilitate the adoption of membrane-brine concentration processes over traditional energy-intensive thermal processes. Past cost-optimization process simulation work suggests that doubling module-level heat or mass transport rates in multi-stage MD[1] and OARO[2] processes for concentrating brine from 100 to 200 g/L would reduce costs by ~18% to ~5.6 $/m^3$ and 20% to ~4.6 $/m^3$, respectively.

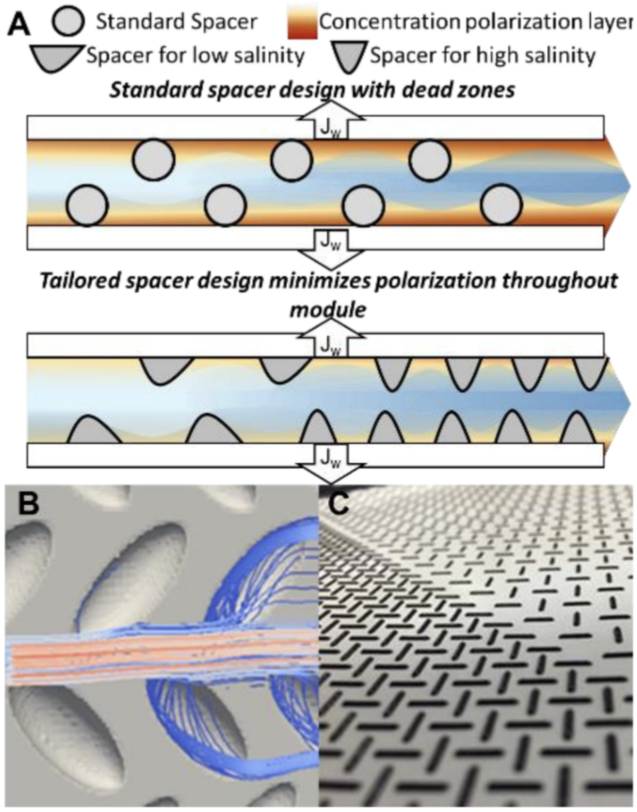

Figure 1. (A) Standard spacers are not tailored for variable conditions across module length. Tailored spacers will mitigate concentration and thermal polarization throughout the module. (B) Example of CFD models resolving flow in a 3D printed spacer topology, such as the one developed by (C) Aqua Membranes.

RESEARCH PARTNERS

Aqua Membranes Inc.: Kevin Roderick, Rodney Herrington; Cascade Technologies; SLAC National Accelerator Laboratory: Alexander Dudchenko, Christopher Takacs; Stanford University: Ali Mani, Ilenia Battiato, Meagan Mauter.

REFERENCES

1. Dudchenko, A. V., Bartholomew, T. V. & Mauter, M. S. Cost optimization of multi-stage gap membrane distillation. Journal of Membrane Science 627, 119228 (2021).
2. Bartholomew, T. V., Siefert, N. S. & Mauter, M. S. Cost Optimization of Osmotically Assisted Reverse Osmosis. Environ. Sci. Technol. acs.est.8b02771 (2018) doi:10.1021/acs.est.8b02771.

This work was supported by the National Alliance for Water Innovation (NAWI), funded by the U.S. Department of Energy, Energy Efficiency and Renewable Energy Office, Advanced Manufacturing Office.

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY