

Research Summary – Zachary Binger, 2021

My research focuses on modeling of membrane processes, specifically system modeling and optimization. I spend most of my time developing my own models in Matlab, Python, and Javascript for investigating membrane systems at the module or system scale and running computational fluid dynamics simulations (CFD) to improve those models. My method for improving the modeling of membrane processes has been guided by a multi-scale approach with previous work focusing on improving models at the system and module scales.

Recently, focus has shifted to refining modeling at the micro-scale by improving the governing equations that describe the transport of water and solutes through a semi-permeable membrane and the hydrodynamic behavior inside the membrane channel. In the latest publication, a solution-diffusion with defects (SDWD) model to describe the transport of water and solutes across a membrane was proposed. This model suggests that a membrane with defects, where the defects operate like a filtration membrane, would allow for a pressure-driven convective flow through the membrane. When compared to experimental PRO results, the SDWD model better predicted the lower-than-expected water permeability and salt retention seen in experimental data compared to previous models.

Ongoing research is focused on extending the micro-scale modeling by refining the estimation of pressure losses inside the membrane modules caused by turbulence promoting spacers, by creating new models powered by machine learning (ML) technologies. Data from computational fluid dynamics (CFD) simulations, that capture an expansive range of potential spacer shapes, will be paired with artificial neural networks (ANNs) to create a more accurate and adaptable pressure loss model to better predict the energy costs associated with operating membrane systems. Furthermore, this CFD-ML framework can be used to rapidly investigate other key hydrodynamic metrics such as residence time, concentration polarization, shear rate, and turbulence promotion that can be used for optimizing spacer geometries to simultaneously improve water recovery and reduce the energy costs of membrane systems.