Announcing the Final Examination of Yuming Fang for the degree of Doctor of Philosophy

Time & Location: June 28, 2013 at 8:30 AM in ENG II 211 P
Title: Study of the Effect of Surface Morphology on Mass Transfer and Fouling Behavior of Reverse Osmosis and Nanofiltration Membrane Processes

The influence of surface characteristics on membrane process performance is considered significant and is not well understood. This work evaluated mass transfer processes by incorporating surface morphology into a diffusion-based model assuming MTCs are dependent on the thickness variation of the membrane's active layer. To mathematically create such a layer, Gaussian random vectors embedded in MATLAB were used to generate a three-dimensional ridge and valley active layer morphologies. A "SMOOTH" script was incorporated to reduce the influence of outlying data. A non-homogeneous solution diffusion model (NHDM) was then developed to account for surface variation through the active layer. The NHDM was further modified by incorporating the concentration polarization (CP) effect. A fouling model was also established to evaluate the significance of surface morphology on membrane fouling behavior.

A series of simulations were performed using operating parameters and water qualities data collected from a full-scale reverse osmosis membrane water treatment plant. Prediction of the total dissolved solid (TDS) permeate concentration was found to be accurate within the 5% to 15% range as an average percentage of difference (APD) using the NHDM developed in this research work. A comparison of the NHDM and a modified NHDM for concentration polarization (CP) with the commonly accepted homogeneous solution diffusion model (HSDM) using pilot-scale brackish water reverse osmosis (RO) operating data indicated that the NHDM is more accurate when the solute concentration in the feed stream is low, while the NHDMCP appears to be more predictive of permeate concentration when considering high solute feed concentration.

To evaluate the impact of surface morphology on RO and nanofiltration (NF) performance, fouling experiments were conducted using flat-sheet membrane and different nanoparticles, which included SiO2, TiO2 and CeO2. In this study, the rate and extent of fouling was markedly influenced by membrane surface morphology. The atomic force microscopy (AFM) images analysis revealed that the higher fouling rate of RO membranes compared to that of NF membranes is due to the inherent ridge-and-valley morphology of the RO membranes. This unique morphology increases the surface roughness, leading to particles accumulation in the valleys, causing a higher flux decline than in smoother membranes. Extended fouling experiments were conducted using RO membranes to compare the effect of different particles on actual water. It was determined that membrane flux decline was not affected by particle type when the feed water was laboratory grade water. On the other hand, membrane flux decline was affected by particle type when diluted seawater served as the feed water. A fouling simulation was hence conducted by fitting the monitored flux data into a cake growth rate model. The model was discretized by a finite difference method to incorporate the surface thickness variation. The ratio of cake growth term \(k_1\) and particle back diffusion term \(k_2\) was compared for different RO and NF membranes. Results indicate that \(k_2\) was less significant for surfaces that exhibited a higher roughness. It was concluded that the valley areas of thin-film membrane surfaces have the ability to capture particles, limiting particle back diffusion.

Major: Environmental Engineering

Educational Career:
Bachelor's of Environmental Engineering, BS, 2006, Dalian Maritime University
Master's of Environmental Science, MS, 2008, Tianjin University

Committee in Charge:
Steven J. Duranceau, Chair, Civil, Environmental, & Construction Engineering
Andrew A. Randall, Civil, Environmental, & Construction Engineering
Dingbao Wang, Civil, Environmental, & Construction Engineering
Cherie Yestrebsky, Chemistry

Approved for distribution by Steven J. Duranceau, Committee Chair, on June 3, 2013.

The public is welcome to attend.