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PII: S0376-7388(16)30179-X
DOI: http://dx.doi.org/10.1016/j.memsci.2016.03.041
Reference: MEMSCI14379

To appear in: *Journal of Membrane Science*

Received date: 18 December 2015
Revised date: 16 February 2016
Accepted date: 20 March 2016

A numerical approach to module design for crossflow vacuum membrane distillation systems

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Abstract

A numerical model for heat and mass transfer in vacuum membrane distillation (VMD) under laminar flow was developed using Computational Fluid Dynamics (CFD). Three-dimensional (3D) simulations of temperature and concentration polarization in single and multiple fibre VMD modules were used to estimate permeate flux (kg m^{-2} h^{-1}) over a range of temperatures (30 – 70 ^{o}C), vacuum pressures (10 – 100 mmHg), crossflow velocities (0.0072 – 0.72 m/s), and feed concentrations (0 – 0.4 kg/L NaCl). Simulated flux differed by less than 7% from experimental data for a module with comparable dimensions. Simulations indicate that a 56% increase in fibre packing density resulted in a 24% flux decline at high operating temperature (70 ^{o}C), and more than 50% flux decline at low crossflow velocity (0.0072 m/s). The effect of vacuum pressure on flux was found to be independent to the module packing density, while the effect of salt concentration was found to be 28% lower than estimates based on Raoult's law, due to lower spatial variations in membrane surface temperatures at higher salt concentrations. The approach developed in this paper may be used to evaluate performance of alternative configurations for VMD models to aid module design, scale-up and process optimization.