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Development of a mathematical model for the prediction of concentration polarization in reverse osmosis desalination processes

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ABSTRACT

Concentration polarization is referred to the buildup of salts on the high-pressure side of the reverse osmosis membrane surface. It is created due to the rejection of the dissolved salts by reverse osmosis membrane while convective flow carries salt up to the membrane surface. Therefore, the salt concentration at the membrane surface increases to a value exceeding the bulk salt concentration producing a salt boundary layer at the membrane surface. Concentration polarization affects the performance of the reverse osmosis process significantly. It increases the osmotic pressure at the membrane surface leading to a reduction in water flux and an increase in salt leakage. Also, the membrane lifetime is susceptible to decrease by high salt concentration, and concentration polarization will aggravate this effect. The present work focuses on the utilization of a combined film theory and diffusion transport through the membrane. In this work, the solution diffusion transport model and film theory will be combined to obtain an explicit expression for the water flux through the reverse osmosis process. This formula will help in the formulation of concentration polarization using limited data on water, salt and membrane properties as well as the mass transfer coefficients. By this approach, a predictive mathematical model for concentration polarization in reverse osmosis desalination processes was developed. The developed model depends on two dimensionless parameters that can be evaluated by providing water and solute permeability coefficients, operating conditions and mass transfer coefficient. The model was verified against published data, and a good agreement was found.

Keywords: Mathematical modeling; Concentration polarization; Membrane processes; Reverse osmosis; Permeate flux

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