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Calculation of energy consumption for crossflow RO desalination processes

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ABSTRACT

Reverse osmosis (RO) is an energy-intensive technology and consistent efforts have been made to reduce energy requirement of the technology in order to make it a more affordable means of water supply. There is an urgent need for a more accurate quantification of energy consumption in the crossflow RO process because it is the predominant configuration used in water desalination and purification. The energy required in the crossflow RO desalination processes is affected by a complex set of parameters or variables, including raw water quality, membrane property, operating requirements such as permeate flux and water recovery, as well as option of energy recovery device in the concentrate stream. The crossflow RO process is fundamentally a heterogeneous system that can only be well defined with the localized variables for the salt concentration, cross flow velocity, and permeate flux along the membrane channel. A theoretical framework was developed in this study for a more accurate quantification of energy consumption in the crossflow RO process by rigorously treating the process as a heterogeneous system as it is. An inverse problem was first solved to determine the driving pressure for a RO process of given set of conditions. The resulted pressure was then used to calculate energy consumption in the RO systems either with fully energy recovery from the concentrate stream or without energy recovery at all. It was demonstrated that the energy consumptions in both RO systems were limited by mass transfer mechanism at low water recoveries but was controlled by thermodynamic restriction at high recoveries. The specific energy (energy consumption for per unit volume of permeate) was calculated for seawater and brackish RO processes for wide ranges of water recovery while the permeate flux was maintained constant at different levels. The specific energy for the RO system with concentrate energy recovery was observed to increase with both increasing permeate flux and increasing recovery. However, there was a minimum at a particular recovery in the specific energy for RO system without concentrate energy recovery and the minimum specific energy shifted to the high recovery end with increasing permeate flux.

Keywords: Specific energy; Reverse osmosis; Desalination; Crossflow; Recovery

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