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Modeling of colloidal fouling in forward osmosis membrane: Effects of reverse draw solution permeation

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HIGHLIGHTS

► A numerical model was developed to simulate the flux decline due to fouling in FO.
► Diffusivity of draw solute plays crucial roles in flux decline due to fouling.
► The amount of reverse draw solution permeation is minor to determine flux decline.

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ABSTRACT

A numerical model for predicting the flux decline due to colloidal fouling was developed for a forward osmosis (FO) membrane system. We derived the kinetic equation of the cake layer growth based on a first-order reaction and control volume approach. Based on the model simulation, it was found that the deposited particles on a membrane surface are proportional to the feed concentration and the permeate flux. Moreover, the simulation result reveals that the cake-enhanced osmotic pressure (CEOP) is a key factor diminishing the permeate flux for large colloidal foulants. For small colloidal foulants, the hydraulic resistance of the cake layer is dominant in flux decline at the beginning of the fouling and CEOP increasingly become significant as fouling progresses. The effects of the reverse draw solute permeation on the flux decline were also simulated. Interestingly, the increased reverse draw solute permeation obtained by increasing the solute permeability showed little effect on the flux decline. Contrarily, variation of the diffusivity significantly influenced the flux decline. Consequently, the numerical model developed in this paper suggests that the selection of draw solute for an FO membrane process should be carefully regarded, along with the fouling mechanism.

1. Introduction

Water scarcity has become a critical issue in recent years, and is likely to spread into essential factors of human life such by affecting our food and energy supply [1]. To this end, the United Nations Educational, Scientific and Cultural Organization (UNESCO) predicts that more than half of the nations around the world will face water shortages by 2025 [2]. As such, this predicted demand for fresh water has increased the need for manufacturing water, and tremendous efforts have been made to develop novel processes for producing reliable water with low energy consumption [3]. As a means of alleviating this water stress, water reuse and desalination technologies are promising since they are relatively independent of the hydrological cycle [4].

To date, pressure-driven processes such as nanofiltration (NF), ultrafiltration (UF), and reverse osmosis (RO) are dominant technologies in water reuse and desalination research [5,6]. However, the inherent reliance of these pressure-driven processes on hydraulic pressure may restrict their sustainable development due to increasingly high oil prices [7]. In recent years, forward osmosis (FO)—an emerging separation process driven by the chemical potential difference of two solutions across a semi-permeable membrane—has been spotlighted as an alternative to pressure-driven processes in certain applications due to its low energy consumption, simplicity, and reliability [8–10]. In addition, since the FO process utilizes a natural driving force (i.e., chemical potential or concentration difference

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