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Procedia Engineering 44 (2012) 256 – 257

Procedia Engineering

www.elsevier.com/locate/procedia

Euromembrane Conference 2012

[OB28]

Polyelectrolytes-promoted forward osmosis processes

Q.C. Ge, M.M. Ling, G. Amy, T.S. Chung*

[1]National University of Singapore, Singapore, [2]King Abdullah University of Science and Technology, Saudi Arabia

Abstract

The development of the forward osmosis (FO) process has been constrained by the slow development of appropriate draw solutions. Two significant concerns related to draw solutions are the draw solute leakage and intensive-energy requirement in recycling draw solutes after the FO process. FO would be much attractive if there is no draw solute leakage and the recycle of draw solutes is easy and economic.

In this study, polyelectrolytes of a series of polyacrylic acid sodium salts (PAA-Na), were explored as draw solutes in the FO process. The characteristics of high solubility in water and flexibility in structural configuration ensure the suitability of PAA-Na as draw solutes and their relative ease in recycle through pressure-driven ultrafiltration (UF) membrane processes. The high water flux with insignificant salt leakage in the FO process and the high salt rejection in UF recycle processes reveal the superiority of PAA-Na to conventional ionic salts, such as NaCl, when comparing their FO performance via the same membranes. The repeatable performance of PAA-Na after recycle indicates the absence of any aggregation problems. The overall performance demonstrates that polyelectrolytes of PAA-Na series are promising as draw solutes, and the new concept of using polyelectrolytes as draw solutes in FO processes is applicable. The magnetic nanoparticle draw solutes can generate reasonably high osmotic pressure in FO system due to the functional groups on the nanoparticles surface and they can be regenerated through magnetic field and reused as draw solutes. Thermo-responsive magnetic nanoparticles are able to be regenerated with high efficiency as the thermo-responsive property can assist the regeneration in a low-strength magnetic field.

Methods

The schematic diagram for the FO-UF hybrid process is depicted in Figure 1. In the FO process, PAA-Na solutions act as draw solutions to extract water through the semi-permeable FO membrane. In the UF process, the PAA-Na solutions diluted in the FO process are reconcentrated and able to reuse in the new round of FO process. Polyelectrolyte meeting the aforementioned requirements is another type of promising draw solutes in FO. Nanoparticles with hydrophilic surface functionality and high surface-area-to-volume ratio can generate high osmotic pressures for desalination purposes. Moreover, the nanoparticles can be readily regenerated using efficient and conventional methods, such as magnetic fields and ultrafiltration. Thermo-responsive magnetic nanoarpticles as ‘smart’ draw solute can be regenerated with high recovery efficiency. Upon heating the thermo-responsive magnetic nanoparticles above the critical temperature, the particles size will increase and thus they can readily capture in a low-strength magnetic field.

doi:10.1016/j.proeng.2012.08.378

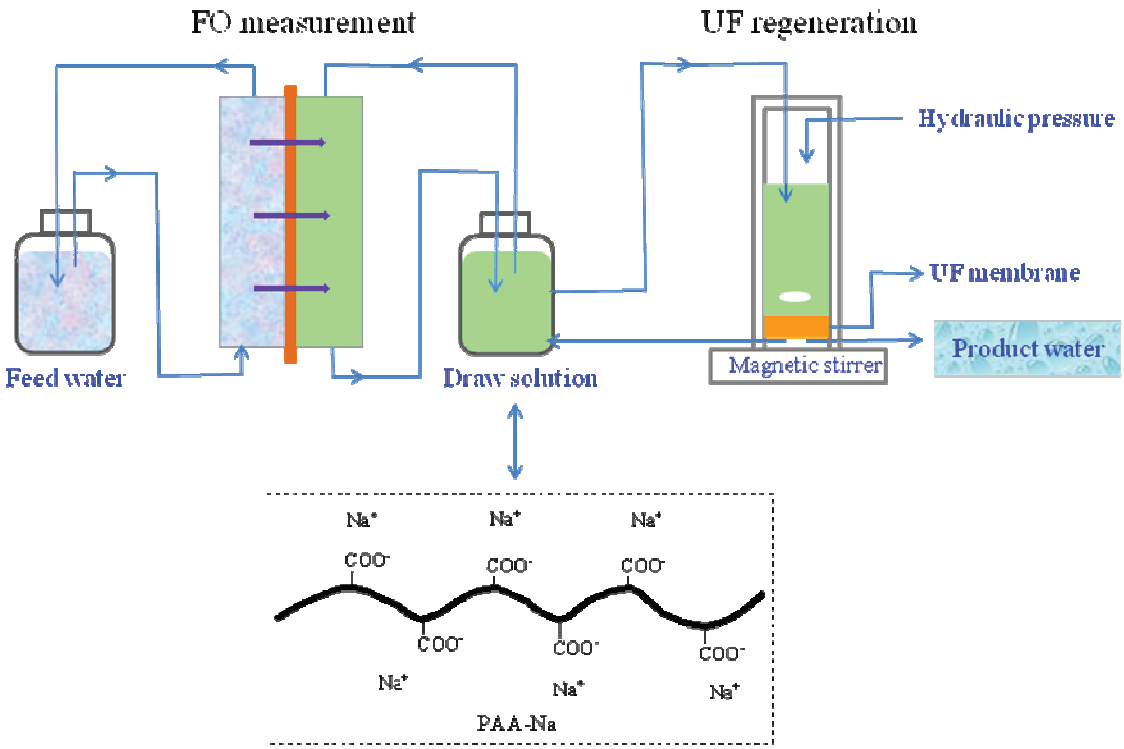

Figure 1. Schematic diagram of the lab-scale FO-UF hybrid system

Keywords: Forward osmosis, draw solute, wastewater treatment, ultrafiltration