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Effect of particle size on the performance of forward osmosis desalination by stimuli-responsive polymer hydrogels as a draw agent

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HIGHLIGHTS

- ▶ The use of hydrogels as a draw agent in forward osmosis (FO) desalination.
- ▶ The effect of hydrogel particle size was examined.
- ▶ The hydrogel particle size affected the water diffusion mechanism during FO process.
- ▶ Better particle–particle contact and particle-membrane contact led to higher FO flux.

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ABSTRACT

Stimuli-responsive polymer hydrogels have shown great potential for use as a draw agent in forward osmosis desalination. We have previously shown that the alteration of chemical structure of hydrogel network via the incorporation of ionic groups and light-absorbing particles can significantly improve the efficiency of hydrogels used as draw agent in FO desalination. In this study, particle size is demonstrated to be another key parameter in determining the efficacy of these materials as the draw media. Hydrogel copolymers of sodium acrylate and N-isopropylacrylamide of different particle sizes were prepared via free-radical polymerization and tested as draw agents. The results showed that the initial swelling rate of small particles (2–25 μm) was much higher than that of large particles (e.g., 500–1000 μm), with the diffusion mechanism shifted from non-Fickian to Fickian diffusion as the particle size decreases. To reclaim the fresh water drawn through the membrane by the polymer particles, the gas pressure and heating were applied as the stimuli on the draw agent to release water. Gas pressure was found to be an effective method of regaining the pure water, and is a more readily applicable method industrially than our previous mechanical pressing. It was found that greater liquid water recovery amounts were achieved from large hydrogel particles, whereas more water was recovered from smaller particles under such a thermal stimulus. This is likely due to the fact that hydrogel particles with different sizes showed different interstitial volumes, particle–particle contact areas, particle-membrane contact zones and hydrogel thickness on the membrane surface.

1. Introduction

The scarcity of fresh water is currently a key global issue with a significant influence on humanity. Desalination using membrane-based processes such as reverse osmosis [1], nanofiltration [2], membrane distillation (MD) [3] and forward osmosis [4] have shown great potential to assist in solving the scarcity of fresh water. Forward osmosis (FO) in particular, is a desalination process that represents an emerging membrane technology by which fresh water can be produced from seawater, potentially at a much lower energy cost compared with other pressure-driven desalination processes. In a typical FO process, a draw agent is used to provide an osmotic pressure gradient which enables water to pass through the membrane from saline water with a low osmotic pressure to the draw solution (agent) with a high osmotic pressure [4]. The impact of the draw agent on FO performance and efficiency is substantial, as is the membrane material. One of the main obstacles for commercial implementation of FO processes is the separation and recovery of the draw agents at a modest energy cost, without compromising their high osmotic pressure [5]. In the selection of draw agents, some key criteria include: non-toxicity (particularly for potable water production), near neutral pH, compatibility with membrane surface and low-cost energy

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