Effect of different draw solutions on concentration polarisation effect in the forward osmosis process: theoretical modelling and experimental validation

Shaoheng Ma [a,b] *(Presenting Author underlined),* Xing Wu[a], Linhua Fan [b], Zongli Xie [a] *

[a] CSIRO Manufacturing, Clayton South, Victoria 3169, Australia

[b] School of Engineering, RMIT University, Victoria 3001, Australia

*Corresponding author:

Zongli.Xie@csiro.au (Z. Xie).

Abstract:

Forward osmosis (FO) is a promising membrane technology to promote water sustainability. However, one of the main issues is the concentration polarisation (CP) effects, including external (ECP) and internal concentration polarisation (ICP), which result in low flux and overall efficiency and limit its full-scale application. Previously, the understanding of the CP effects was only focused on NaCl-based draw solutions. This study explored four different draw solutions (NaCl, KCl, Na_2SO_4, $MgCl_2$) in to obtain more comprehensive knowledge. The solution diffusion (SD) model was utilised for understanding the intrinsic CP effects change under different conditions. The experimental and the model results showed that when the draw solution concentration continuously increased, a significant proportion of the theoretical osmotic pressure (OP) of draw solution lost in the CP effects, especially in ICP. Exploring the proportion of the CP phenomenon and the effective osmotic pressure showed that CP effects became more prominent with increasing draw solution concentration. Comparing the resulting OP through different draw solutes, it was revealed that the one with fewer ions dissociated, higher diffusivity coefficient and low viscosity allows solutes to diffuse freely and maintains higher effective OP proportion, and therefore is preferable. In addition, it was implied that flow rate could be manipulated to reduce the ECP effects at the draw solution side because of excellent mixing in the draw solution and minimising the boundary layer. However, the increased concentration at the membrane surface exaggerated the ICP, and the advantage was offset. Hence, the water flux was not improved significantly. These findings could help provide guidelines for further optimisation of the FO systems.

Keywords: Forward osmosis, process modelling, concentration polarisation, draw solution