Pressure Assisted Osmosis (PAO) to enhance Forward Osmosis (FO) Performance

Kerusha Lutchmiah1,2, D.J.H. Harmsen1, B. Wols1, A.R.D. Verlieefde2,3, J.W. Post1 and E.R. Cornelissen1

Introduction

Forward osmosis (FO) is a concentration-driven membrane process using an osmotic solution. Advantages of FO:

• low energy consumption
• high product quality and
• lower fouling propensity compared to state-of-the-art pressure-driven membrane processes i.e. reverse osmosis

Typical fluxes obtained for spiral wound FO elements are 5-7 L/m²h for a 0.5 M NaCl osmotic draw solution (Cornelissen et al. 2011; Hancock et al. 2011; Xu et al. 2010); active layer (AL) facing the feed side (FS).

Objectives of the research

This study uses additional hydraulic pressure on the FS to investigate PAO, which aims to:

• Reduce internal concentration polarisation (a limitation of FO)
• Increase FO membrane performance (i.e. increase water flux, decrease reverse salt flux)

Materials and methods

1. Modeling of water and solute flux in PAO

• ODE obtained from the solute transport equation in the membrane support layer (SL) (Figure 1).
• FO water flux (Jw) based on diffusion and additional hydraulic pressure difference (ΔP) over the membrane by increasing the feed pressure (PF):

\[ J_w = A(\pi_f - \pi_i) + AP_f \]  

(1)

A: water transport coefficient
i: osmotic pressure at interface of AL and the membrane SL
F: osmotic pressure of FS

• Solving the ODE using the boundary conditions for the AL-FS, the following equation can be obtained for the solute concentration at the interface of the AL and the SL in PAO mode:

\[ \frac{J_{w}}{K_m} = ln \left( \frac{\rho_f J_{w0}}{\rho_i J_{w0} + (A(F)\pi_f + B)} \right) \]  

(2)

B: solute transport coefficient
F: osmotic pressure of the draw solution
Jw,PF: water flux without additional hydraulic pressure
Km: mass transport coefficient (depends on the structural parameter).

2. PAO lab-scale experiments

PAO laboratory experiments were carried out in an FO set-up (Fig. 2).
• Membrane: HTI Explorer type FO membrane (area = 112 cm²)
• FS: DI-water, DS: 0.5 M NaCl
• applied pressure range: 0-1 bar (only on the FS)

Results

• FO flux increased with an increase in the feed pressure for both the PAO model and experiments.
• Experimentally, the FO flux increased significantly (<50%) when an additional feed pressure was applied (Figure 3). This is contradictory to calculated FO flux values which only increased slightly.
• Pressurising FO membranes can possibly change the water transport coefficient (A). This was not considered in the transport model, but will depend on the type, structure and material of the FO membrane.

Conclusions

• PAO might increase FO performance; however, the effect of PAO will be dependent on the type, structure and material of FO membranes.
• Further work focuses on the effects of (i) PAO on reverse salt transport and (ii) the effect of continuous PAO and discontinuous PAO operation (results not included).
• Possible mechanical breakdown due to additional feed pressure and pulsation might be an issue.

Literature


1 KWR, PO box 1072, 3430 BB Nieuwegein, The Netherlands
2 Delft University of Technology, Stevinweg 1, 2628CN, Delft, The Netherlands
3 Ghent University, Coupure Links 653, 9000 Ghent, Belgium

For more information: emile.cornelissen@kwwater.nl