

(Short Paper)

Evaluation of Membrane Fouling in a Pressure Retarded Osmosis System

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Abstract

This study evaluated the fouling of a forward osmosis membrane in a pressure retarded osmosis (PRO) system using Aldrich humic acid (AHA) as a model foulant. Fouling behaviour was evaluated quantitatively by observation of the decline in water permeability in the fouling tests: when AHA and CaCl₂ were added to the feed solution (FS), severe fouling (51 % decline) occurred; when only AHA was added to FS, moderate fouling (23 % decline) occurred. Photographs of the membrane surfaces after fouling tests indicate that the severe fouling is due to the formation of a dense layer of cross-lined AHAs with Ca²⁺ on the membrane surface of the FS side.

Key Words : Pressure retarded osmosis, Fouling, Humic acid, Calcium ion

1. Introduction

Recently, there have been many reports on pressure retarded osmosis (PRO) power generation¹⁾. PRO converts the energy of the salinity gradient between draw solution (DS) and feed solution (FS) passing through a forward osmosis (FO) membrane into electricity. Despite much research into PRO, membrane fouling in PRO has not been investigated to date²⁾. Membrane fouling causes a decrease in the permeate water flux, $J_w(t)$, over time, t . However, in many PRO test reports¹⁾, $J_w(t)$ was also diminished by a decrease in the osmotic pressure difference between the DS and FS sides, $\Delta\pi(t)$. Hence, it is difficult to evaluate the fouling behaviour only by monitoring the decline in $J_w(t)$. In this study, a quantitative evaluation of fouling in PRO systems was performed by using the apparent water permeability of an FO membrane obtained from $J_w(t)$ and $\Delta\pi(t)$.

2. Experimental

A commercial FO membrane [Hydration Technologies Innovation] was used in this study. It has an asymmetric structure of cellulose triacetate (CTA) with an embedded polyester mesh³⁾. Aldrich humic acid [AHA, Sigma-Aldrich] was selected as a model organic foulant. Three types of FS: (FS-I), 50 mM NaCl; (FS-II), 50 mM NaCl and 500 ppm AHA; (FS-III), 45 mM NaCl, 5 mM CaCl₂ and 500 ppm AHA; were used. A fouling test was performed with an evaluation system (Fig. 1). $J_w(t)$ was measured by the weight change

in the FS tank. The change in $\Delta\pi(t)$ was obtained from the concentration change between the DS and FS tanks in terms of the van't Hoff equation. The apparent water permeability in PRO mode, $A^{PRO}(t)$, is given as:

$$A^{PRO}(t) = \frac{J_w(t)}{(\Delta\pi(t) - \Delta P)} \quad (1)$$

where ΔP is the hydraulic pressure difference between DS and FS.

3. Results and Discussion

Fig. 2 shows the change in $A^{PRO}(t)$ during fouling tests. The $A^{PRO}(t)$ of FS-I was almost a constant value, indicating clearly that no fouling occurred. When AHA was added to FS (FS-II), the 23 % decline in $A^{PRO}(t)$ at 3 h, indicated that moderate fouling occurred. When FS contained AHA and

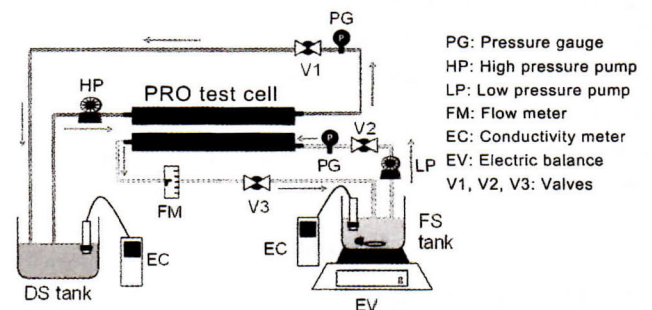


Fig. 1 An evaluation system for fouling tests in PRO

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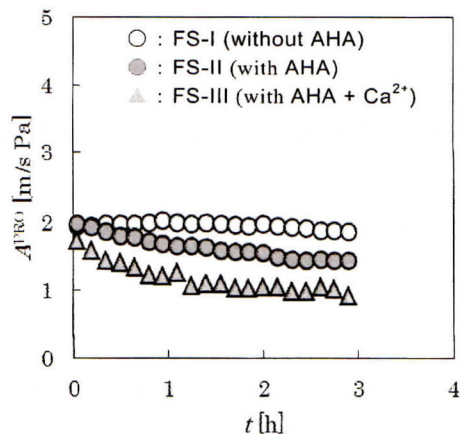


Fig. 2 The change in the water permeability of PRO mode during elapsed time. PRO conditions: DS, 2 M NaCl; AL-facing-DS; $\Delta P = 0$; temperature, 25 °C; the linear velocity of DS and FS are 8.5 and 2.2 cm/s, respectively.

Ca²⁺ ions (FS-III), $A^{PRO}(t)$ decreased 51 % at 3 h, meaning that more remarkable fouling occurred.

In FS-I, there was no colour change in the membrane surface of both the active layer (AL) and support layer (SL) sides (Fig. 3a and 3b). In FS-II, the membrane surface of both the AL and SL sides was brown (Fig. 3c and 3d). In FS-III, the surface of the AL side was light brown (Fig. 3e) while that of the SL side was dark brown (Fig. 3f). This indicates that in the case of FS-II, AHA in FS will be adsorbed in the CTA layer and distributed around the polymer layer; hence, the surface of both AL and SL sides were stained with a brown colour by AHA as shown in Fig. 4a. On the other hand, in the case of FS-III, Ca²⁺ ions in FS bound with AHA molecules and the cross-linking of the organic macromolecules by the divalent cations formed a compact, dense and thick fouling layer⁴⁾, appearing as a dark brown surface (Fig. 3f). This dense fouling layer caused the remarkable decline in $A^{PRO}(t)$ as shown in Fig. 2. The light brown surface on the AL side (Fig. 3e) indicates that the cross-linked AHAs hardly permeate through the SL into the AL of the CTA membrane because of the bulky structure of the cross-linked AHA molecules. This provided a heterogeneous distribution of AHAs inside the polymer layer of the membrane as shown in Fig. 4b.

4. Conclusion

In this study, the fouling mechanism of a CTA FO membrane in a PRO system was investigated using the apparent water permeability, $A^{PRO}(t)$, obtained from the permeate water flux and the osmotic pressure difference

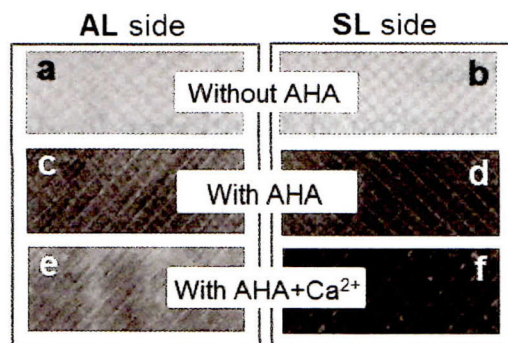


Fig. 3 Photographs of the surfaces of the CTA membrane after the fouling test. AL, active layer; SL, support layer.

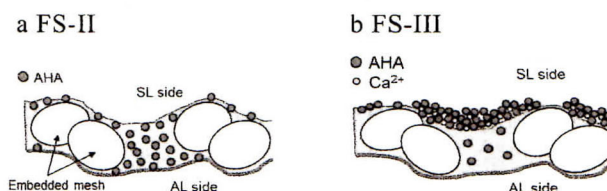


Fig. 4 Schematic diagram of the cross-section of a CTA membrane after the fouling tests.

between the DS and FS sides. The change in $A^{PRO}(t)$ and photographs of the membrane surfaces after the fouling tests revealed that when FS contained AHA and Ca²⁺ ions, severe fouling occurred and formed a dense fouling layer of cross-linked AHAs on the surface of the SL side.

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