Investigation on Organic Fouling of Forward Osmosis Membrane Modified by Chemical Grafting

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ABSTRACT: Forward Osmosis (FO) membrane is one of the membrane technologies used in water treatment. However, some of the disadvantages of membrane technology is fouling as it affects the efficiency of the membranes. The membrane fouling contributes to the declination of permeate flux. The result of fouling leads to a blockage towards the membrane surface and requires a high maintenance cost. In this study, commercial Polyethersulfone Nanofiltration (NF) membrane has been modified by chemical grafting using different monomer concentration of methacrylic acid (MA) and initiators potassium persulphate ($K_2S_2O_8$) and sodium metabisulfite ($Na_2S_2O_5$) at different grafting time. The fouling index has been studied by using humic acid (HA) as model of natural organic matter (NOM). An increment in fouling index was observed as the membrane grafting degree increases. The membrane suffered of severe fouling with highest fouling index of 91.5% when modified using highest monomer MA concentration (1M) at longest grafting time (30min). Therefore, the optimum modification conditions are required to produce FO membrane with minimum fouling index.
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Keywords: *Forward osmosis; Organic fouling; Humic acid;*

1. INTRODUCTION

FO system employs natural osmotic pressure as it separates and solutes two solutions with different concentrations across the semipermeable membrane. These two-solution known as draw solution which has a high concentration while the other side of the membrane has feed solution with lower concentration. Since FO employs natural osmotic pressure, no cake formation will occur on the membrane due to zero hydraulic pressure.

A major disadvantage in membrane technology is fouling on the membrane surface. Various aspects of mass transport lead to the accumulation, attachment, or adsorption of particles onto membrane surfaces and pores, causing membrane fouling [1]. The contaminants in feed water that results in membrane fouling include inorganic compounds, dissolved organics, chemical reactants, colloidal or particulate matter, microbial products, and microorganism [2]. One of the examples of natural organic matter commonly found in the surface water is humic acid.

Previously, surface modification in the membrane field have been focused on the addition of more hydrophilic monomer for fouling resistant [3]. Surface modification effectively improved the integrity of the membranes and further elevates their overall performance. One of the successful surface modification methods is chemical grafting. Previously, chemical grafting was successfully applied for modification of commercial polyamide NF membrane for FO application but it was limited to water flux and reverse solute diffusion study only [4]. Thus, the objective of this paper is to investigate the effect of the chemical grafting in FO membrane towards organic fouling (humic acid) using commercial polyethersulfone NF membrane as substrate.

2. METHODOLOGY

2.1 *Chemical Grafting*

The NF membrane was immersed in an aqueous solution mixture containing monomers (MA) with redox initiators which are potassium persulfate ($K_2S_2O_8$) and sodium metabisulfite ($Na_2S_2O_8$). The modification of the membrane was manipulated with different MA monomer concentrations (0.3, 0.6 and 1M) and grafting times (10, 20, and 30 minutes). Three samples were prepared for each modification.

2.2 *FO Setup*

Lab-scale FO cross-flow filtration system unit was used to study the performance of FO membrane. For FO performance, 1 M of NaCl was applied as draw solution (DS) in all the experimental works. The initial water flux $\boldsymbol{F_i}$, was measured using dionized water as a feed solution (FS). Then, filtration was conducted with a 15 mg/L humic acid (HA) solution as the feed solution. Mass of permeate change was recorded every 10 minutes for 4 hours. The weakly adsorbed humic acid was then removed from membrane by flushing the membrane again with deionized water for 15 minutes. Finally, the membrane was tested again with deionized water, and the final water flux, $\boldsymbol{F_f}$ was measured. The fouling index term in term of irreversible fouling, IF was calculated by using the following equation 1.

$$IF = \left(1 - \frac{F_f}{F_i}\right) \times 100\% \qquad (1)$$

3. RESULTS AND DISCUSSION

The performance of the membrane was determined by the fouling index. In this study, the fouling index is mainly attributed to the humic acid deposition on the membrane surface or/and inside the pores. Figure 1 shows there is an increment in fouling index as the grafting time increased from 10 min to 30 min. This trend clearly can be observed for membrane modification with lower concentration of MA (0.3 M and 0.6M). However, no clear trend can be deduced for highest MA concentration of 1M. As can be seen in Figure 1, membrane modified with lowest concentration of 0.3M and shortest grafting time (10 min) shows the lowest fouling propensity with fouling index IF=21.71%. While the modified membrane with the highest monomer MA (1M) and longest grafting time (30min) exhibited severe fouling (IF=91.5%). It is proved that there is an increment in index fouling as the fouling more severe with increasing of the grafting degree. This might be due to changes of membrane surface morphology and structure after modification have an impact on membrane performance characteristics. Generally, roughness has a very significant impact on the increasing of fouling propensity. The smoother membrane surfaces were linked with higher flux, whereas the rougher membrane surfaces were related to severe fouling [5,6]. Compared to unmodified NF membrane (Fig.2a) and membrane modified at lower 0.3M MA concentration (Fig.2b), it is clear that membrane modified at highest MA concentration (1M) exhibited rougher surface with larger granule distributed on the membrane surface as shown in Figure 2c. This rougher surface will permanently trap mores humic acid solutes during the filtration process and lead to a severe fouling.

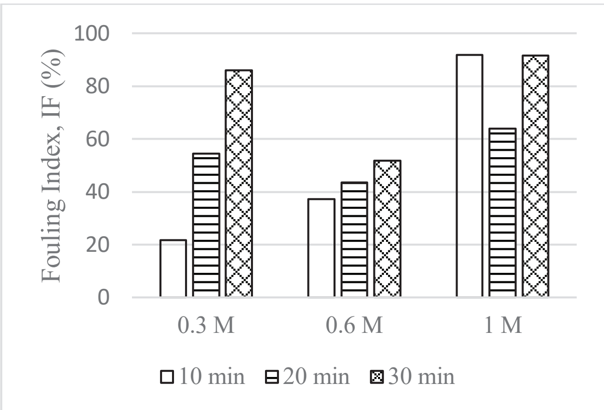
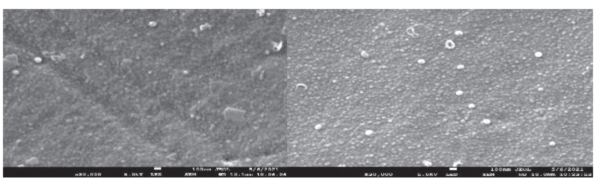
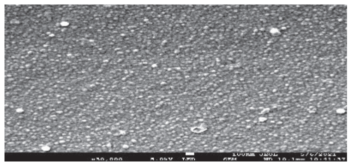


Figure 1: Fouling index for membrane modified at different MA concentration (0.3, 0.6 & 1M) and grafting time (10, 20 & 30 min)



(a) (b)



(c)

Figure 2: Top surface FESEM images of 30,000× magnifications of (a) unmodified NF, (b) modified with 0.3M of MA, (c) modified with 1M of MA

4. CONCLUSION

Overall, the modification of the commercial NF membrane has been successfully modified via chemical grafting for FO application. The membrane surface has been physically changed during the grafting process especially the surface roughness. This has a considerable impact on the fouling with the highest fouling index (IF=91.5%) was observed for rougher membrane surface modified at highest monomer concentration (1M) and longest grafting time (30min). Therefore, membrane surface morphology (i.e. roughness) plays an important role in minimizing fouling.

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