INFLUENCE OF POLYETHYLENE GLYCOL (PEG) ADDITIVE ON PERFORMANCE POLYSULFONE (PSf) AND POLYETHERSULFONE (PES) MEMBRANE

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ABSTRACT

This paper focuses on the performance of polysulfone (PSf) and polyethersulfone (PES) ultrafiltration membranes with polyethylene glycol (PEG). The flat sheet membranes were prepared via phase inversion method that casting dope solution consists of polysulfone (PSf) and polyethersulfone (PES) separately as polymer, while N-methyl-2-pyrrolidone (NMP) as solvent material. PEG 400 was used as a pore forming additive in the casting dope solution. The morphology of membranes was analyzed by scanning electron microscopy (SEM). The performance of membranes was evaluated in terms of pure water flux (PWF) and humic acid (HA) rejection. The effect of different concentration of PEG additive exhibits significant improved on PSf and PES membrane performance. The results indicated that PES ultrafiltration membrane exhibits good performance in PWF as compared to PSf membrane. It was found that the pure water flux increased as the PEG concentration increases (0 to 8 wt %) in casting solution. As a result, the morphology of membranes prepared with high concentration of PEG has larger pore size.

Keywords: Polysulfone; polyethersulfone; polyethylene glycol; pure water flux.

INTRODUCTION

Membrane technology has a unique place in many industrial and water management applications. Millions of preventable deaths in developing countries are due to microorganism, which come from the polluted drinking water. In order to solve this problem, ultrafiltration (UF) process can be useful to remove the contaminants from the pollute water. Generally, UF is considered as a very promising process for drinking water production because of its compactness, easy automation and high removal rate of turbidity, organic matter and virus. With pore diameters from 10A to 1000A, it is usually defined to be limited to membranes and UF is recognized as a low pressure membrane filtration process [Mulder, 1991]. The most widely used polymer for the UF preparation membrane are polysulfone (PSf) and polyethersulfone (PES). Generally, PSf and PES are characterized by SO_2 linkages, which give the polymers high strength. They also are rigid, tough thermoplastic with glass transition temperature, T_g of 180-250˚C and excellent high temperature properties and chemical inertness [Seader and Henley, 2006].

The main disadvantage of polysulfone and polyethersulfone is being hydrophobicity, which leads to an apparent tendency to interact strongly with a variety of solutes thus prone to fouling [Cheryan, 1998]. This problem can be overcome with some modification into membrane by adding some additive. Shied et al. extended that PEG being hydrophilic in nature, can be used to improve membrane selectivity and as a pore forming agent [Shieh et al., 2001]. Previous studies showed that the addition of polyethylene glycol (PEG) acts as a pore forming agent and also affects the thermodynamics and kinetics of the phase inversion process. Kim et al. systematically studied the effect of PEG on membrane formation by phase inversion [Kim and Lee, 1998]. The study showed that by increasing the ratio of PEG additive to solvent NMP, the casting solution becomes thermodynamically less stable. Membrane pore size becomes larger and the top layer becomes more porous.

In this study, the effect of different concentration of PEG 400 of polysulfone and polyethersulfone membrane on pure water flux, humic acid rejection and morphology were investigated and discussed in detailed. Polyethylene glycol (PEG 400) was used as pore forming additive to improve the permeability of membrane. The membrane performance was evaluated via cross flow filtration method.

EXPERIMENTAL

Materials

Polysulfone and polyethersulfone were separately used as the base polymer in the membrane casting solution. PSf and PES were dried with temperature 60˚C for 24 hours before use. N-menthyl-2-pyrrolidione (NMP) from Merck was used as solvent. Polyethylene glycol 400 (QRec) was used as additive and pore forming agent in the dope solution. Distilled water was used as the main non-solvent in the coagulation bath for phase inversion purposes.

Membrane Preparation

PSf membrane and PES membrane were prepared by phase inversion method. Casting solutions containing of PSf and PES (separately), NMP and different concentration of PEG 400 (0, 6 and 8 wt%). PSf and PES polymer were separately dissolved in NMP and stirred and heated at 60˚C for several hours by mechanical stirrer at 500 rpm and room temperature. Then, additive was added with continuous stirring until the dope solution completely dissolved and homogeneous. After completely homogenous, the dope solution was kept in ultrasonification machine in several hours for removing the air bubbles. The dope solution was poured onto glass plate at room temperature and it was casted by using a casting knife. After casting, the glass plate with casted film was dipped into distilled water. The cast films changed their colour from transparent to white immediately after immersion into coagulation bath. The membrane was washed and kept in distilled water for several hours. The flat sheets were air dried at room temperature for more than 24 hours before testing.

Membrane Characterization

Scanning Electron Microscopy (SEM) was used to examine the flat sheet membrane morphology. The membranes were cut into pieces of small sizes and were immersed in liquid nitrogen for several seconds. Then, membrane samples were fractured carefully and coated by gold before testing.

Pure Water Flux (PWF) and Rejection (R)

The permeation flux and rejection of the prepared membranes were measured by an ultrafiltration cross flow test at 3 bars. The flat sheet membrane sample was cut into a circle shape with area of 2.376×10^{-3} m^2 was placed in the test cell with the active skin layer facing the incoming feed. The pure water flux experiments using distilled water as feed whereas rejection experiments using humic acid. The volume of permeate was collected and measured. Membrane performance of pure water flux (PWF) for PSf and PES ultrafiltration membrane were calculated from the equation (1) as below:

$$PWF = Q/(A x \Delta t) \qquad (1)$$

PWF in (L/m^2h), where Q is volume of permeate (L), A is membrane surface area (m^2) and Δt is permeation time (h). Rejection was characterized with 100 mg/L humic acid after the PSf and PES membrane was filtered with distilled water. The concentration of feed and permeate solution were determined by using UV spectrophotometer (Shimadzu UV-160) at wavelength of 254 nm against a reagent blank. Rejection percentage was calculated using following equation (2):

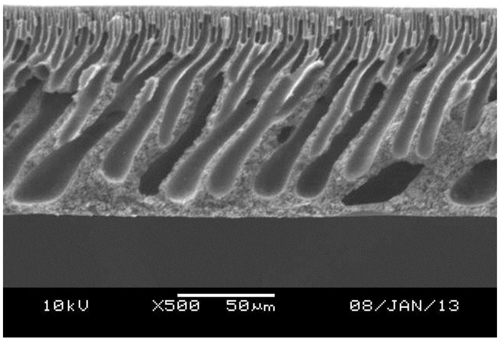
$$R(\%) = [1- (C_p/C_f)] \times 100 \qquad (2)$$

Where R (%) is rejection percentage, C_p is concentration permeates and C_f is concentration feed.

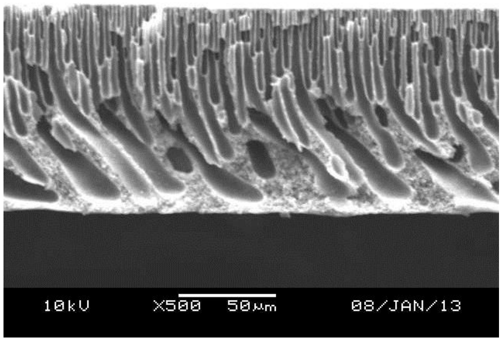
RESULTS AND DISCUSSION

Morphology of PSf and PES Ultrafiltration Membrane

As a result of the image of PSf and PES ultrafiltration membrane generated by SEM it can be observed through the image as shown in Figure 1 and Figure 2 respectively. It can be observed that PSf and PES membrane having asymmetric porous structure which is consisting dense top layer on the top of membrane, porous sub layer at intermediate and sponge-like structure at bottom surface layer. Based on Figure 1 and Figure 2, it is clearly shows that by increasing of PEG concentration in casting solution, the porous finger-like structure size at top surface of membrane is increased. By referring to previous study [Idris et al., 2007], since concentration is increased the macrovoids increased in number and size, then enhancing the formation of many finger-like pores of membrane. These figures also presented the spongy bottom layer, it may due to slow precipitation of membrane during immersion into coagulation bath after casting process. Basically in phase inversion process, the formation of membrane structure is depends on thermodynamic principles of casting solution [Mulder, 1991].



(a)



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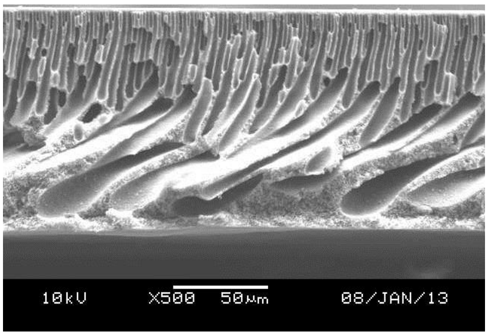
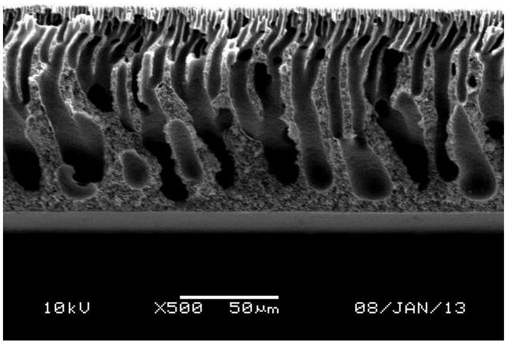


(c)

Figure 1: Cross section of SEM images of PSf membrane with different concentration of PEG (a) 0 wt% PEG, (b) 6 wt% PEG (c) 8 wt% PEG



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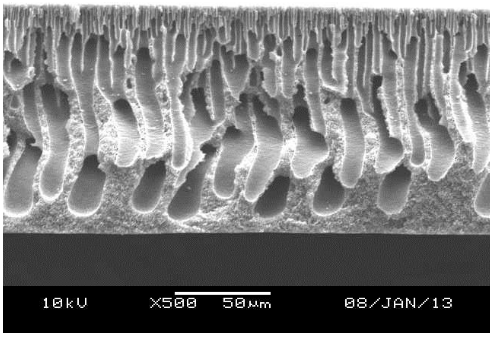

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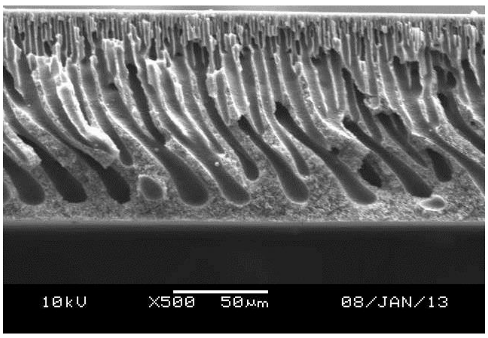

(c)

Figure 2: Cross section of SEM images of PES membrane with different concentration of PEG (a) 0 wt% PEG, (b) 6 wt% PEG (c) 8 wt% PEG

Pure Water Flux (PWF) and Humic Acid Rejection

Pure water flux performance

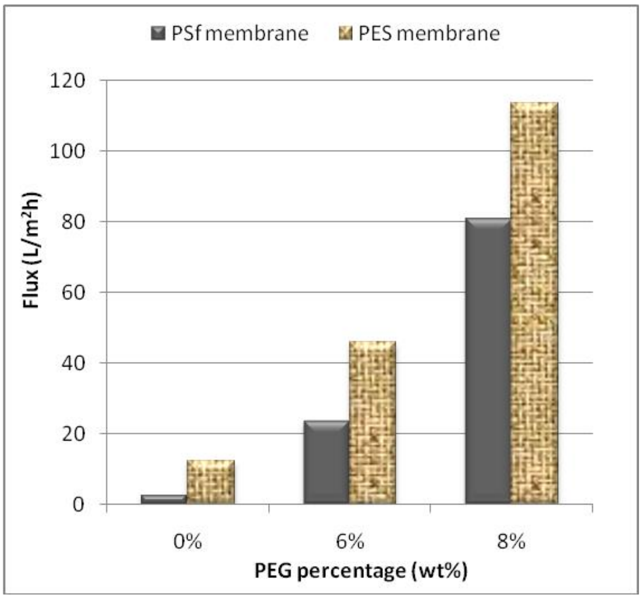

Figure 3: Pure water flux permeation for PSf and PES membrane

Figure 3 clearly indicated that the pure water flux (PWF) performance of PSf and PES membrane is significantly improved by increasing percentage of polyethylene glycol (PEG 400) added into casting solution. From the figure, the flux performance of PSf membrane is increase as percentage of PEG increased from 0 wt% (2.70 L/m^2h) to 8 wt% (80.81 L/m^2h). PES ultrafiltration membrane that containing polyethylene glycol as additive has increased pure water permeation from 12.12 L/m^2h to 113.64 L/m^2h, when concentration of PEG is increased from 0 to 8 wt%. Based on pure water permeation, PES membrane gives better performance in increasing flux compared to PSf membrane. This situation is due to the pore enhancement when percentage of PEG increased in casting solution. Based on previous studies, PEG acts as pore forming agent to increase pore structure of membrane [Shieh et al., 2001], since PEG additive has hydrophilic properties, it gives better interaction between membrane surface and water permeation. The research of Liu et al. showed that PEG can be used to enhance polymer which is PES solution viscosity and to enhance pore interconnectivity when added in appropriate amounts [Liu et al., 2003].

Humic acid rejection performance

The effect of PEG 400 as additive for permeate flux and humic acid (HA) rejection on PSf and PES membrane is clearly presented in Figure 4 and Figure 5 respectively. Based on bar graph plotted in Figure 5, humic acid rejection performance of PSf and PES ultrafiltration membrane are not significant different. The highest rejection performance on PSf and PES membrane is 98.5%. Meanwhile, permeate flux of both ultrafiltration membrane are decreased as the percentage of PEG additive is increased in the casting solution. As a result, PSf membrane is from 2.45 L/m^2h to 62.70 L/m^2h when percentage of PEG additive is increased. Permeation flux of HA for PES membrane is from 11.62 L/m^2h to 89.22 L/m^2h as increased of PEG 400.

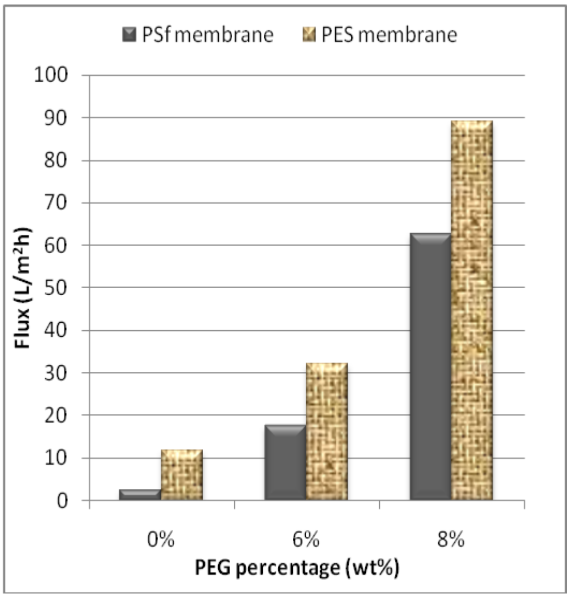

Figure 4: Humic acid permeation flux for PSf and PES membrane

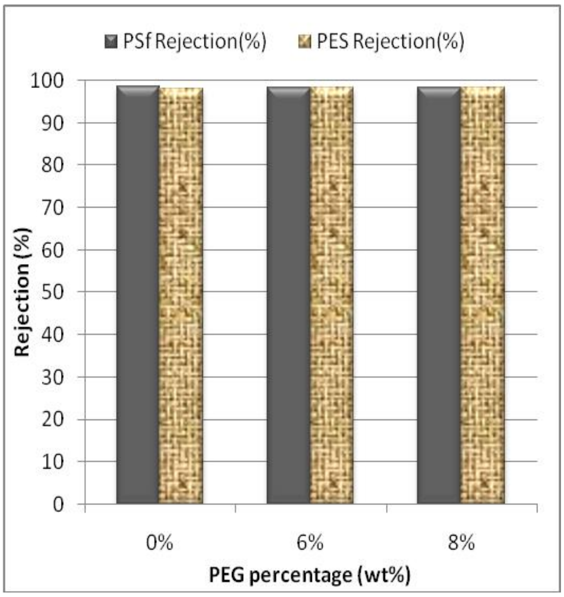

Figure 5: Rejection results for PSf and PES membrane

CONCLUSION

In conclusion, the presence of polyethylene glycol of different concentration as additives exhibits significant affected on PSf and PES ultrafiltration membranes. Addition of different concentration (0 wt%, 6 wt% and 8 wt%) of polyethylene glycol as additive in casting solution influences the morphology structure, pure water flux performance and humic acid rejection of membrane. PES ultrafiltration membrane consist PEG 400 show an excellent increase in pure water flux compared to PSf membrane.

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