Influence of Brij 58 on the Characteristic and Performance of PES Membrane for Water Treatment Process

Mukramah¹, Syawaliah¹, S Mulyati² and N Arahman²*

¹Graduate school of Engineering, Universitas Syiah Kuala
²Department of Chemical Engineering, Universitas Syiah Kuala.
Jl. Tengku Syech Abduorrauf No. 7, Darussalam, Banda Aceh 23111, Indonesia

*nasrulan@unsyiah.ac.id

Abstract. This study proposes a modification of polyether sulfone (PES) membrane by blending the polymer with a hydrophilic additive of Brij-58. Flat-sheet PES membrane was prepared through a non-solvent induced phase separation (NIPS) method using dimethylformamide (DMF) as a solvent. PES membrane was modified by adding Brij-58 into dope solution at a different concentration, i.e. 1, 3, 5, 7, and 10 wt %. The fabricated membranes were characterized by means of Scanning Electron Microscopy (SEM) and Fourier Transform Infra-Red (FTIR) spectroscopy. Filtration performance of membrane was analyzed by using a dead-end module. It is found that the addition of a small amount of Brij into polymer solution brought about the increase of water flux. FT-IR investigation showed that the additive exist on the surface of a blended membrane.

1. Introduction
Membrane filtration in water treatment has been known to be a more attractive technology in recent years as a possible alternative treatment for a conventional clarification. The separation process using the membrane is commonly used in industry because the process does not require any chemical additives [1], operation temperature rooms and has low operating costs, and high permeability [2]. Furthermore, it is considered as an effective process for the production of clean water due to the fact that it has the high level of turbidity removal [3].

The membrane can be produced from a number kind of materials. However, the type of the materials used will affect the characteristics of the membrane, such as mechanical strength, fouling resistance, hydrophobicity, and hydrophilicity [4]. Polyether sulfone (PES) is an organic polymer generally used in various types of membranes manufactures, such as microfiltration [5], ultrafiltration [6], nanofiltration [7] and reverse osmosis [8] due to the characteristics of it (PES) which has good chemical resistance, thermally stable, and a glass transition temperature Tg of 230°C [9].

A general method for producing porous polymeric membrane is done by a phase inversion method. Fabricated membrane, if done by the phase inversion method, involves three main components, they are the polymer, solvent, and non-solvent. Moreover, additives are usually used to improve the surface properties of the membrane. Adding the third component into casting solution has become one of the important techniques used in a membrane preparation. In addition, adding organic and inorganic into
the casting solution has been reported as a pore-forming agent and a membrane-modifying agent[10].
Throughout the past three decades, a large number of non-ionic surfactant could be used as the pore
forming agent. For instance, Cailing et al [11] succeeded to make the hydrophilic PES flat sheet
membrane by blending surfactant Pluronic F127. The total fouling membrane and irreversible fouling
membrane decreased (with an increase of the Pluronic F127 contents).

In this study, we used surfactant Brij 58 (Mw = 1124) as the third component of the PES membrane
formation in order to produce a membrane with stable pore density. PES flat sheet membrane was
prepared through a non-solvent induced phase separation process. The effect of adding surfactant Brij-
58 on the performance of the final PES flat sheet membrane was investigated.

2. Methods

2.1. Materials
Polyether sulfone (PES, Ultra son E6020 P) was the main polymer in forming a membrane with Mw
65,000 and it was purchased from BASF Co. Dimethylformamide (DMF) functioning as a solvent. DI
water was used as non – solvent in coagulation bath, Brij58 with the molecular weight of 1,124
functioning as surfactant additive, and humic acid functioning as the artificial sample for water
contamination.
Glass plate as a media support and casting knife was used to cast the membrane. Coagulation bath, a
dead-end ultrafiltration (UF) module was used to measure the performance of fabricated membrane and N₂
gas cylinder for pressure supply.

2.2. Membrane preparation
Flat sheet polyethersulfone (PES) membrane was prepared through a non – solvent induced phase
separation (NIPS). A casting solution was prepared by dissolving PES in DMF (solvent). PES
concentration was fixed at 18 wt %. In addition, Brij 58 concentrations were varied at 0, 1, 3, 5, 7 and
10 wt%. The polymer solution was cast on the glass plate by using a film applicator. The cast membrane
and plate were then instantly sunk in the coagulation bath of deionized water to complete the phase
separation. The composition of the casting solution is shown in Table 1.

| Membrane         | PES (wt%) | DMF (wt%) | Brij 58 (wt%) |
|------------------|-----------|-----------|---------------|
| PES original     | 18        | 82        | 0             |
| PES + 1% Brij    | 18        | 81        | 1             |
| PES + 3% Brij    | 18        | 79        | 3             |
| PES + 5% Brij    | 18        | 77        | 5             |
| PES + 7% Brij    | 18        | 75        | 7             |
| PES + 10% Brij   | 18        | 72        | 10            |

2.3. Characterization of membrane
The Characterization of the fabricated membranes in this study included membrane morphology
(surface) observed using Scanning Electron Microscopy (SEM), and the membrane surface
compositions were characterized using Fourier Transform Infrared (FTIR) Spectrophotometer
(Shimadzu, Japan).

2.4. Water flux measurement
A dead-end UF module was used to measure the water flux of the prepared membranes at varied feed
pressure. Pressurization was provided by using an N₂ gas cylinder, and the system was equipped with a
50 mL volume of feed reservoir. The membrane was pressurized at 0.5; 1; 1.5; and 2 bars during
filtration of DI water for 1 hour. Afterward, DI water was filtered through the membrane, and the weight
of permeate was measured on a digital balance. The pure water flux was calculated by using Equation (1)[9]:

$$J = \frac{\Delta V}{A \times \Delta t}$$  

where $J$ is Flux ($\text{L/m}^2\cdot\text{h}$), $V$ is permeate volume ($\text{L}$), $A$ is the effective membrane area ($\text{m}^2$) $t$ is the permeation time for DI water (h).

2.5. Preparation of humic acid (HA) solution

The humic acid solution was prepared according to the procedure used by [12]. A stock solution of 50 ppm HA was prepared by dissolving 50 mg HA powder into 1 L DI water. This solution was stirred 24 h. Then, HA solution from stock solution was diluted to 10 ppm which was then used as a sample solution.

3. Result and Discussion

3.1. Influence of Brij 58 on morphology of the membrane

In order to understand the effect of adding of Brij 58 on the membrane morphology, surface of the membranes was observed using SEM. The surface structure of PES membrane without and with the addition of Brij58 are presented in Figure 1. The membrane composed with nodule and pores structure. The addition of hydrophilic additive in this system brought about the increase of pore size and pore density of membrane.

![SEM images of surface membrane fabricated from PES, PES/Brij (5wt%), and PES/Brij (10wt%)](image)

**Figure 1.** SEM images of surface membrane fabricated from PES, PES/Brij (5wt%), and PES/Brij (10wt%)
The addition of surfactant Brij 58 generate membranes with more porous sublayer. The addition of additives into the polymer solution can also lead the formation of macrovoid in the center path membrane. The changes in the membranes morphology related to the interaction between the components in the casting solution[13].

3.2. Fourier Transform Infrared (FTIR) Spectrophotometer analysis

Fourier Transform Infrared (FTIR) Spectrophotometer was an instrument used to determine the functional groups contained in a membrane sample. The FTIR recorded data by the molecular interaction in the form of absorbance or transmittance of infrared rays given to the sample. The FTIR analysis could provide information about the functional groups contained in the membrane. The result of the FTIR analysis of PES membrane without blending with Brij-58 is shown in Figure2. As can be seen in Figure 2, the IR spectra of pure PES membrane denoted by a sulfone group located around wavenumber of 564.14 cm$^{-1}$ represent of SO$_2$ from the polymer material. In addition, there was the absorption on benzene ring in the aromatic compound at a wavenumber of 1485.19 cm$^{-1}$.

FTIR experiment was also observed the existence of Brij 58 on the surface of modified membrane. Figure 3 depicted the comparison of IR spectra of pure and modified PES membrane with Brij58. In general, the spectra did not show the significant differences because the polymer used was the same (PES). However, the intensity of the peak at a wavenumber of 2920.23 cm$^{-1}$ of the IR spectra of the modified membrane with surfactant Brij 58.
3.3. Influence of Brij 58 on pure water permeability

Pure water permeability could be measured by measuring the pure water flux. The test of water flux was conducted by calculating the volume of permeate obtained per unit time and unit area of the active surface of the membrane. The water flux could indicate the influence of the concentrations of Brij 58 on the dope solution. Membranes with a higher pore density have a higher water permeation [14]. After the flux value was obtained at various pressures (0.5 bar, 1 bar, 1.5 bar and 2 bar), the test result of it was used to calculate the coefficient of water permeability (Lp). The pure water permeability was obtained from the graphic slope of the relationship between the flux and trans-membrane pressure. The higher the value of Lp, the more easily water passed through the membrane. Therefore, it would produce a high flux value.

![Figure 3. FTIR spectra for pure PES membrane and modified PES membrane.](image)

**Figure 3.** FTIR spectra for pure PES membrane and modified PES membrane.

![Figure 4. Pure water permeability coefficient of fabricated membrane](image)

**Figure 4.** Pure water permeability coefficient of fabricated membrane
Based on Figure 4, it could be seen that the permeability coefficient of the PES/Brij-58 membranes increased in comparison with that of the original PES membrane. The graph showed that the permeability coefficient increased from 2.084 L/m².h.bar to 52.1 L/m².h.bar after adding 7 wt% of Brij 58 and then decreased with the addition of 10 wt% of Brij 58 to the casting solutions.

Pure water permeability is membrane's ability to pass water based on a pressure rise. The pressure used was 0.5, 1, 1.5, and 2 bars. The permeability coefficient could indicate the type of the membrane produced. According to [9], membrane with Lp <50 L/ m².h.bar is classified in hyperfiltration membrane, Lp 50-500 L / m².h.bar is classified in ultrafiltration membrane and Lp> 500L / m².h is classified in microfiltration membrane. The water permeability coefficient obtained in this study can be seen in Table 2 below.

Table 2. Pure water permeability coefficient of PES membrane with varying concentration of Brij 58

| Brij 58 content (wt%) | Lp (L/m².h.bar) | Type      |
|-----------------------|-----------------|-----------|
| 0                     | 2.084           | hyperfiltration |
| 1                     | 7.84            | hyperfiltration |
| 3                     | 35.46           | hyperfiltration |
| 5                     | 50.71           | ultrafiltration |
| 7                     | 52.1            | ultrafiltration |
| 10                    | 13.95           | hyperfiltration |

3.4. Influence of Brij 58 on HA flux and rejection

The fabricated membranes were tested in dead – end ultrafiltration module of 10 ppm HA solution to evaluate its performance in removal of humic acid. The HA solution was filtered for 30 minutes by using the fabricated membrane at 1 bar feed pressure. Then, the HA concentration in retentate and permeate were analyzed by using Spectrophotometry UV – visible at wavelength 254 nm. The rejection (R) was given by [9]

\[% R = 1 - \frac{C_p}{C_r} \times 100 \]  

(2)

Where \(C_p\) is the solute concentration in the permeate and \(C_r\) is the solute concentration in the retentate.

![Figure 5. HA flux and rejection of the prepared membrane](image_url)
Based on Figure 5, it could be seen that the humic acid flux increases with increasing the concentration of Brij 58 in the dope solution. The humic acid flux of modified membrane was higher than original PES membrane. But on the other hand, the rejection value decreases, inversely proportional to the increase the value of flux. The higher the value of flux HA produced, the lower the selectivity is generated. The highest rejection value was obtained on the pure PES membrane, namely 94.758%. While, the highest flux value produced by the membrane with the addition of 7 wt% Brij 58, namely 58.60757 L/m².h.

4. Conclusion
Modification of flat sheet polyethersulfone (PES) membrane was conducted by adding Brij58 of different concentrations as membrane pore forming agents into the dope solution. The addition of additive with different concentration greatly contributed to the morphology and performance of the resulting membranes. SEM images exhibited that the modified membranes had more porous than that of without modification. Furthermore, the ultrafiltration experiment indicated that the fabricated membranes with the addition of 7 wt% Brij 58 showed higher pure water permeability coefficient.

Acknowledgment
The author would like to express their thanks to the Ministry of Research, Technology and Higher Education of the Republic of Indonesia for the financial support.

References
[1] Lin J, Zhang R, Ye W, Jullok N, Sotto A, Bruggen B V 2013 J Colloid Interf Sci396 120 – 128
[2] Jamshisi G R, Halakoo E, Nazri N A M, Lau W J, Matsuura T, Ismail A F 2014 Desalination335 87 – 95
[3] Gao W, Liang H, Ma J, Han M, Chen Z L, Han Z, Li G 2011 Desalination272 1 – 8
[4] Basile A, Gallucci F 2011 Membranes for Membrane Reactors. Preparation, Optimization and Selection (United Kingdom)
[5] Ghandashtani M B, Ashtiani F Z, Karimi M, Fouladitajar A 2015 Appl Surf Sci349 393 – 402
[6] Said M, Ahmad A, Mohammad AW, Nor MTM, Abdullah SRS 2015J Ind Eng Chem21 182 – 188
[7] Wang L, Song X, Wang T, Wang S, Wang Z, Gao C 2015 Appl Surf Sci330 118 – 188
[8] Kim E S, Liu Y, El-Din M G 2011 Sep Purif Techno/81 418 – 428
[9] Mulder M 1991 Basic Principles of Membrane Technology(Netherland) Kluwer Academic Publisher
[10] Omidvar M, Soltanien M, Mousavi S M, Saljoughi E, Moarefian A, and Saffarian H 2015 J Environ Health Sci Eng131 – 9
[11] Lv C, Su Y, Wang Y, Ma X, Sun Q, Jiang Z 2007 J Membrane Sci294 68 – 74
[12] Mehrparvar A, Rahimgour A, and Jahanshahi M 2013 J Taiwan Inst Chem.E45 275 – 282
[13] Omidvar M, Soltanien M,Mousavi S M, and Safekordi A A 2014 J Environ Health Sci Eng12 1 – 9
[14] Moarefian A, Golestani HA, and Bahmanpoor H 2014 J Environ Health Sci Eng12 1-10