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Performance and characterization of PEG400 modified PVC ultrafiltration membrane

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Abstract. Polyvinyl chloride (PVC) ultrafiltration membrane was prepared by blending 12 wt.% of PVC in N, N-dimethylacetimide (DMAc) with polyethylene glycol 400 (PEG400) as an additive. The influence of PEG400 concentration on the PVC membrane morphology, permeability, fouling and rejection were investigated. Fouling and rejection of the PVC membrane were characterized by dextran T-100 filtration. The results showed that membrane water flux was increased up to 682 $Lm^{-2}h^{-1}$ when 28 wt.% of PEG400 was added into the PVC membrane solution. The best membrane performance with a low fouling and a high selectivity was achieved by adding 12 wt.% concentration of PEG400, which resulted in 90% rejection of dextran and 90% of flux recovery ratio. At further addition of PEG400 concentration, irreversible fouling was starting to increase. A 90% of irreversible fouling was formed in the PVC membrane when more than 22 wt.% of PEG400 is added.

Keywords: ultrafiltration; PVC membrane; additive; hydrophilic; fouling

1. Introduction

Polyvinyl Chloride (PVC) membrane has been considered as a promising and an effective technology for drinking water production due to its simplicity in operation with good separation performance (Guo *et al*. 2009b). In addition, PVC membrane provides excellent chemical properties and high resistance to pH, chemical, temperature, and microbial corrosion with a low of material cost, which encourages the growth of production in industrial-scale (Zhang *et al*. 2009). Despite of its advantages, the PVC membrane is limited by its nature of hydrophobic that leads to low permeability, low selectivity, and susceptible to fouling (Guo *et al*. 2009a). Several modifications of PVC membrane have been performed, such as blending PVC with different types of materials (Mei *et al*. 2011a), chemical grafting (Liu *et al*. 2007, Maziad *et al*. 2002, Vigo and Uliana 1989), plasma treatment (Vigo *et al*. 1988, Zhang *et al*. 2006), and UV Irradiation (Kim *et al*. 2002).

Morphological structure of PVC membranes that prepared by phase inversion methods have

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been studied by several researchers. Hirose *et al*. (1981) studied the formation of PVC membrane structure by immersion precipitation method (Hirose *et al*. 1981). PVC was dissolved in dimethylformamide (DMF) to form homogenous casting membrane solution, then casted on a flat glass and immersed into alcohols or ether. They found that the PVC membrane structure could be manipulated by controlling the nature of phase separation parameters, such as coagulant type and concentration of PVC in membrane solution. Okuno *at al*. (1993) continued their study by investigating the influence of casting solution additive, degree of polymerization, and polymer concentration on pervaporation PVC membrane performances (Okuno *et al*. 1993). It was found that characteristics of the PVC membrane solution, particularly the crystallinity degree of PVC, affect the membrane performances significantly. The increase of PVC membrane crystallinity deteriorated the membrane permeability, solubility and diffusivity. The influence of PVC molecular weight on PVC membrane characteristics has been investigated by Bodzek and Konieczy (1991). Different molecular weights of PVC resulted in different viscosity of casting membrane solution that controlled the membrane morphology structure.

Blending PVC with hydrophilic materials is a simple method to overcome its hydrophobic properties. Babu and Gaikar (1999, 2000) blended different types of hydrophilic additives, i.e. carboxylated poly(vinyl chloride) (CPVC) and polyvinylpyrrolidone (PVP) into PVC membrane solution (Babu *et al*. 1999, 2000). The results showed that the PVC/PVP membrane provided higher water flux and rejection of bovine serum albumin (BSA) than PVC/CPVC membrane. Xu and Xu (2002) observed the effect of molecular weight of PVP and polyethylene glycol (PEG) on membrane morphology and permeability (Xu and Xu 2002). It was found that the addition of PVP or PEG increased the PVC membrane porosity and improved its water flux. Mei et al (2011) found that the addition of a low concentration of sucrose in PVC membrane solution changed kinetic characteristic of the PVC membrane solution and suppressed the macrovoid formation in membrane structure (Mei *et al*. 2011b). The presence of additive enhanced viscosity of the membrane solution that exhibited the growth of membrane pore during the formation of membrane structure in coagulation bath (Barth *et al*. 2000, Torrestiana-Sanchez *et al*. 1999).

Beside of membrane materials, fouling is a critical issue in membrane water treatment field since it affects the efficiency of the treatment process and leads to an increase of hydraulic resistance (Nguyen *et al*. 2011). Chemical cleaning is necessary used to remove the foulants and restore the membrane flux, which impacts to the additional of operational cost (Tian *et al*. 2010, Zhang *et al*. 2011). Therefore, fouling control on ultrafiltration (UF) membrane plays an important role during water treatment processes for maintaining a stable performance of the membrane. Many researches have confirmed that membrane fouling was rightly related to the surface property, especially the membrane hydrophilicity (Jucker and Clark1994, Liu *et al*. 2012, Ma *et al*. 2001). Babu and Gaikar (1998 and 2000) showed that the presence of PVP and CPVC reduced the fouling resistance of bovine serum albumin (BSA) on the PVC membrane (Babu and Gaikar 1999, 2000). Chakrabarty *et al*. (2008b) investigated the effect of molecular weight of PVP on BSA fouling in polysulfone membrane (Chakrabarty *et al*. 2008b). They found that fouling of BSA on the PVC membrane was increased by the increase of PVP molecular weight, which contributes to membrane flux decline. In addition, the membrane flux decline was also attributed by the decrease of average membrane pore size as the increase of molecular weight of PVP.

Polyethylene glycol (PEG) is another hydrophilic polymer that commonly used as additive to improve membrane hydrophilicity (Ma *et al*. 2011, Sinha and Purkait 2013). PEG is less frequently used compared than PVP, however PEG has the same important role to the final membrane structure (Liu *et al*. 2003). Xu and Xu (2002) (Bellona *et al*. 2004) found that with an increase of PEG molecular weight from 200 to 10,000 Da in dope solution, the membrane structure was changed from finger-like to ellipsoids with lower mechanical properties. In the present work, a low molecular weight of PEG (400 Da) was used as an additive to improve the PVC membrane performance, while maintaining mechanical properties of the membrane. PVC membrane was prepared by dissolving PVC in N,N-Dimethylacetamide (DMAC), then blended with PEG400. The concentration of PEG400 was increased up to 28 wt.% to investigate the effect of its concentration on PVC membrane morphology, hydrophilicity, fouling, and rejection characteristics. Morphology of the membrane was analyzed by scanning electron microscopy (SEM), meanwhile membrane hydrophilicity was measured by water contact angle (WCA). Fouling and rejection characteristics were investigated by dextran T-100 filtration.

2. Experimental

2.1 Materials

PVC resin with degree of polymerization 700 (PVC type FJ-57) was supplied by PT Asahimas Chemical (Cilegon, Indonesia). N, N-dimethylacetimide (DMAc, 99.9% purity) was obtained from Shanghai Jingsan Jingwei Chemical CO., Ltd without further purification. In this research, PEG400 was used as an additive. Dextran T-100 with MWCO 100,000 Da was used as testing solution to characterize fouling and rejection of the PVC membrane. Demineralized water was used as coagulant to induce the formation of membrane structure.

2.2 Preparation of PVC membrane

Asymmetric membrane was prepared by immersion precipitation method with demineralized water as coagulant. The PVC resin was dissolved in DMAc, then mixed with PEG 400. The membrane solution was stirred for around 12 hours in closed stirred tank until homogenous and left without stirring until no bubbles are appeared. Afterwards, the membrane solution was casted on a flat glass plate with 200 μm thickness and immediately immersed into coagulation bath filled with demineralized water, until all solvent in membrane structure is removed. The casting membrane composition is shown in Table 1.

2.3 Characterization

2.3.1 Scanning Electron Microscope (SEM)

The morphology of PVC membrane was analyzed by Scanning Electron Microscopy (JEOL JSM-6510/LV/A/LA). The sample was broken after dipping in nitrogen liquid, then coated with gold cross-section of membrane structure.

2.3.2 Flux and selectivity measurement

Pure water permeability of PVC membranes were measured by membrane separation unit on cross-flow configuration. Prior to the experiment, circular flatsheet membrane was placed inside a membrane module and rinsed by demineralized water for 30 minutes at 1 atm. The active surface area of each membrane is 45 cm^2. Pure water flux (PWF) was determined by using demineralized water at a fixed pressure, followed by dextran flux measurement. The dextran filtration was operated for two (2) hours (120 minutes), where the flux measurement and sampling were

Table 1 Casting membrane composition

Membrane code	Casting membrane composition (%-wt)		
	PVC	PEG	DMAc
1	12	0	88
1	12	8	80
2	12	10	78
3	12	12	76
4	12	14	74
5	12	16	72
6	12	18	70
7	12	20	68
8	12	22	66
9	12	24	64
10	12	26	62
11	12	28	60

conducted periodically every 20 minutes. PWP and dextran flux was calculated by the following equation

$$J_{W1} = \frac{Q_w}{A} \tag{1}$$

where J_{W1} is permeation flux of PVC membrane ($\mathrm{Lm^{-2}\,h^{-1}}$), Q_w is volumetric rate of solution (L/h), A is membrane surface area ($\mathrm{m^2}$). Dextran flux is mentioned as J_t that is calculated by the same equation as Eq.(1).

2.3.3 Dextran rejection

Dextran solution (0.01 g/L) was fed into membrane separation unit at the same operating condition in PWP measurement. The obtained permeate was reacted with phenol and dissolved in concentrated sulfuric acid to provide gold color solution. The dextran content in raw water and permeate solution were analyzed using UV/vis spectrophotometer at 488 nm wavelength. Meanwhile, the dextran rejection (R) was calculated by the following equation

$$R(\%) = \left[1 - \left(\frac{C_p}{C_f}\right)\right] \times 100 \tag{2}$$

where C_p and C_f are concentration of dextran in permeate and feed solution.

2.3.4 Flux recovery ratio and flux loss

After two (2) hours of dextran solution filtration, the flat sheet membrane was flushed by demineralized water for around 45 minutes. Then, pure water flux (PWF) of the cleaned membrane was measured, which denoted as J_{W2}. Flux recovery ratio (FRR) was calculated by Eq. (3) to investigate the membrane fouling during dextran filtration.

$$FRR(\%) = \left(\frac{J_{W2}}{J_{W1}} \right) \times 100 \tag{3}$$

Flux loss due to reversible (r_r) and irreversible (r_{ir}) fouling in polysulfone membrane were also calculated. Reversible fouling (*rr*) is formed by gel formation on membrane surface, which can be easily removed by flushing or backwash method. Meanwhile, irreversible fouling (r_{ir}) is pore blocking fouling that should be removed by chemical cleaning. In this research, both reversible and irreversible flux loss are evaluated by flushing method. The flux loss was calculated by the following equation

$$r_r = \frac{J_{W2} - J_t}{J_{W1}} \tag{4}$$

$$r_{ir} = \frac{J_{W1} - J_{W2}}{J_{W1}} \tag{5}$$

Total flux loss (r_t) is the sum of r_r and r_{ir}.

2.3.5 Water contact angle

The water. To minimize the experimental error, the water contact angle was measured at five posicontact angle on the PVC membrane surface was measured by static sessile drop method to investigate the membrane hydrophilicity. In this research, demineralized water was used as probe liquid in all of the measurementtion randomly.

2.3.5 Resistance-in-series model

The total resistance in PVC membrane was calculated by the resistance-in-series model, as shown in Eq. (6).

$$J = \frac{\Delta P}{\mu R_t} = \frac{\Delta P}{\mu (R_m + R_f)} \tag{6}$$

ΔP is transmembrane pressure (bar), μ is viscosity of solution (bar.h), R_t is total resistance (m^{-1}), R_m is membrane resistance (m^{-1}), and R_f is fouling resistance (m^{-1}). The membrane resistance (R_m) was determined by filtering demineralized water through the membrane, then calculated by the following equation

$$R_m = \frac{\Delta P}{\mu J_{W1}} \tag{7}$$

After two (2) hours of peat water filtration, the peat water flux was measured in order to calculate the total fouled membrane (R_{ft}). Then, R_f was determined by subtracting the membrane resistance (R_m) from the total fouling resistance (R_{ft}), as shown in Eq. (8).

$$R_f = R_{ft} - R_m \tag{8}$$

3. Result and discussion

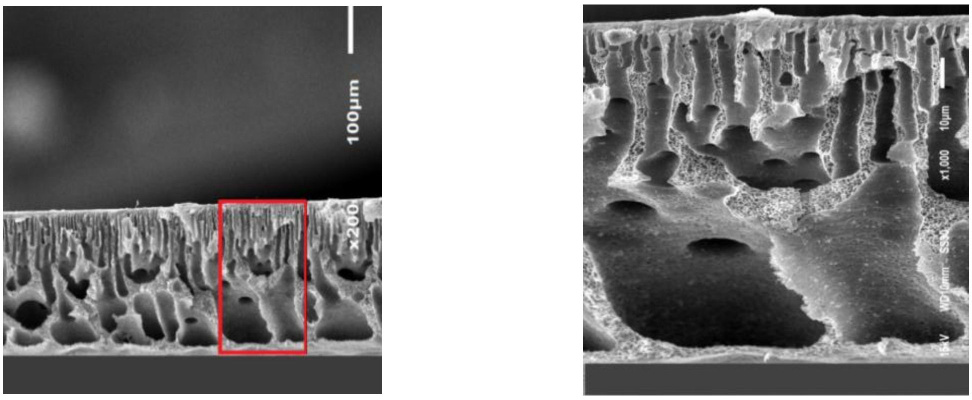
The following section analyzes the effect of PEG400 concentration on membrane morphology and performances. The resulted membrane is categorized as two types of membranes, namely unmodified and modified membrane that prepared by blending PVC in DMAc without or with the addition of PEG400. The experimental results provide a basis data for rational selection of the membrane solution composition, which result in high permeability and rejection during water treatment processes.

3.1. The effect of PEG400 concentration on modified PVC membrane morphology

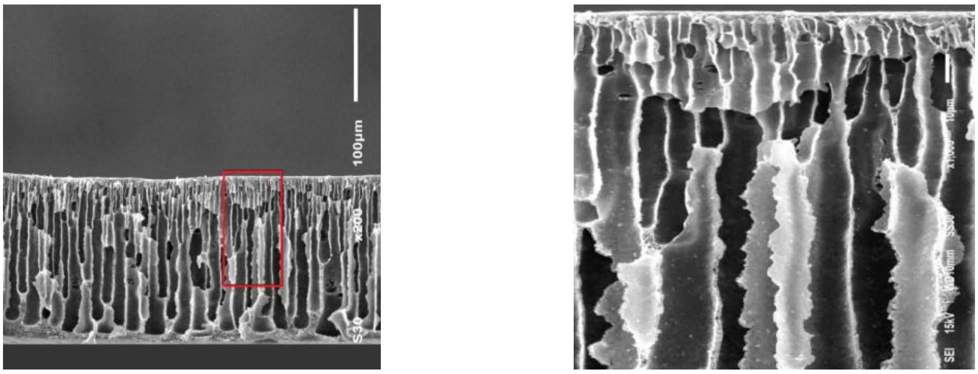
An asymmetric membrane with dense skin layer and finger-like structure is immediately formed when the casting solution is immersed into coagulant bath (Radovanovic *et al*. 1992, Ren *et al*. 2010, Stropnik and Kaiser 2002, Wijmans *et al*. 1983). The membrane structure is formed due to the differences in solution rate and diffusion rate between components in the membrane solution (polymer and solvent) and coagulant (non-solvent) (Kim and Lee 2003). Several researches and reviews have been conducted to study the important parameters during membrane preparation. It has been well-known that the presence of additive in membrane solution influences the thermodynamic and kinetic of the formation of asymmetric UF membrane (Boom 1992, Zheng *et al*. 2006).

Fig. 1 presents the SEM photographs of PVC membrane's cross-section with different PEG400 concentrations. In the absence of PEG400 (Fig. 1(a)), some macrovoid cavities are formed in the membrane sub-layer. The membrane structure formation is initiated by the diffusion of water (non-solvent) into the membrane solution and DMAC (solvent) out from the membrane solution. High mutual affinity between DMAc and water contributes in instantaneous demixing when immersed in coagulation bath, which forms macrovoid cavities in the membrane sublayer (Chakrabarty *et al*. 2008a, Koenhen *et al*. 1977). These macrovoid cavities could be suppressed by the addition of PEG400 into membrane solution, as shown in Fig. 1B. The increase of solution viscosity due to the presence of PEG400 prevents the growth of pore in membrane structure kinetically. However, the entrapped PEG400 generates further water diffusion into polymer solution and thus enhances the polymer precipitation. Since water is a strong non-solvent, the coagulation occurs rapidly when the polymer solution is brought into contact with water, which leads to the instantaneous demixing and forms finger-like structures (Chakrabarty *et al*. 2008a, Kim and Lee 1998).

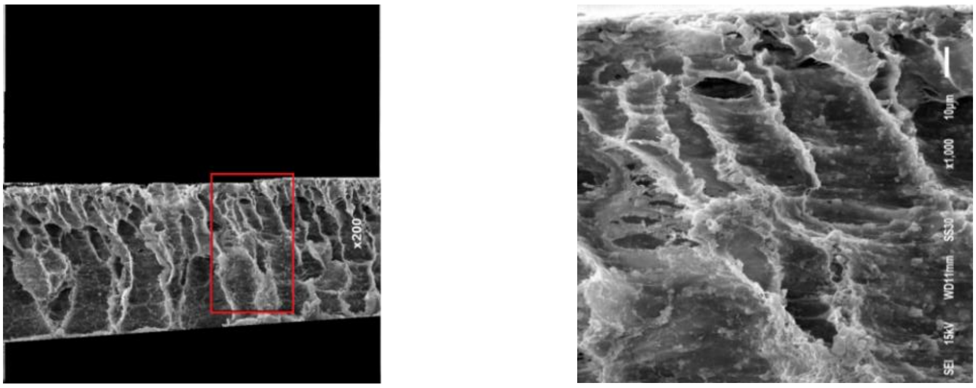
When 28 wt.% concentration of PEG400 is added (Fig. 1(c)), macrovoid cavites are formed at the bottom layer of the PVC membrane. High concentration of PEG400 enhances diffusion rate of water into the membrane solution, hence induces macrovoid formation. The evaporation of DMAc from membrane solution contributes to the increase of solid and water content in membrane solution that creates viscosity and surface tension gradient along of the membrane thickness (Khare *et al*. 2002, Peng *et al*. 2008). Consequently, high solution viscosity inhibits the formation of macrovoids. Meanwhile, lower solution viscosity combined with low surface tension at the bottom of membrane layer allows the growth of macrovoids. At the same time, higher polymer concentration is also formed at the top layer of the membrane attributed by solvent evaporation (Reuvers and Smolders 1987). High solid concentration at the top layer as the increase of PEG400 concentration results in thicker membrane skin layer. On the other hand, the agglomeration of PEG400 molecules entrapped in membrane matrix is detectable in Fig. 1(c), which is indicated by rough surface on the membrane cross-section. It may be attributed by high viscosity of the membrane solution and the segmental gap formed between the components in the blend system because of its incompatibility (Rajesh *et al*. 2011).



(a) 0 wt.% of PEG400



(b) 16 wt.% of PEG400



(c) 28 wt.% of PEG400d

Fig. 1 SEM photographs of PVC membrane with addition PEG400. Magnifician: 200× (left) and 1000× (right) magnification

3.2. Hydrophilicity and rejection characteristic on modified PVC membrane

In this research, hydrophilicity of the PVC membrane is measured by water contact angle (WCA) on the membrane surface. Influence of PEG contents on measured WCA is shown in Fig. 2. The addition of PEG400 contributes to the reduction of WCA, which indicates that the membrane hydrophilicity has enhanced. Higher concentration of PEG400 in membrane solution enhances the entrapped PEG400 in polymer matrix. Consequently, lower WCA measurement is obtained due to improvement of interaction between the membrane surface and the water droplets. The addition of 28 wt.% of PEG400 enhances the membrane hydrophilicity up to 80 wt.% compared with the unmodified membrane.

The improvement of PVC membrane hydrophilicity contributes to increase the PWF, as seen in Fig. 3. Very low PWF is achieved on the unmodified membrane due to its hydrophobicity. The PWF is starting to increase when 10 wt.% PEG400 is added into the PVC membrane solution. Further increase of PEG400 concentration up to 28 wt.%, the PWF is drastically raised from 48 to 681 $Lm^{-2}h^{-1}$ or enhanced until 17 times than the unmodified membrane. This results can be

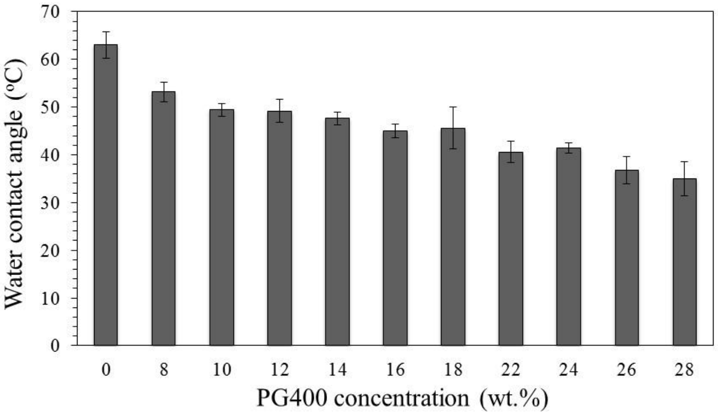


Fig. 2 Effect PEG400 concentration on Water Contact Angle (WCA) of membrane

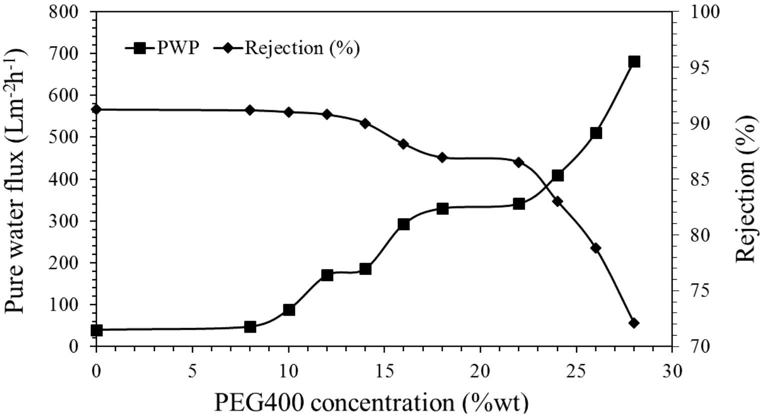


Fig. 3 Effect of PEG400 concentration on of PWP and dextran rejection

explained by referring to Fig. 1, which shows that higher concentration of PEG400 induces the formation of finger-like pore in membrane structure. High diffusion rate of water into membrane solution due to the presence PEG400 contributes to the formation of higher polymer-lean phase, which allows the growth and coalescence of the membrane pores.

Many researchers have studied a trade-off between membrane selectivity and permeability that is known as one of the drawbacks in polymeric membranes (Lee *et al.* 2003, Geise *et al.* 2011). This trade-off is also found in this research, where the dextran rejection is decreased by the increase of membrane hydrophilicity. More than 90% rejection of dextran is resulted when less than 14 wt.% of PEG400 is blended into PVC membrane solution. Meanwhile beyond the said concentration, the dextran rejection is decreased. The decrease of dextran rejection may be affected by the formation of open pore in membrane skin layer due to the presence of PEG400 (Aryanti *et al.* 2013, Kim and Lee 1998). Hence, this leads to the increase of solute content in the permeate.

3.3. Fouling characteristic on PEG400 modified PVC membrane

Profile of dextran flux during two (2) hours of filtration is presented in Fig. 4. It shows that the dextran flux appears to stable in the addition of PEG400 content up to 12 wt.% and declines slightly after 40 minutes of dextran filtration. This flux loss is predominantly attributed by the accumulation of dextrans on the membrane surface.

Rapid flux decline begins to occur when more than 16 wt.% of PEG400 is added into the membrane solution. It is predicted that the formation of open pores in membrane skin layer at high concentration of PEG400 leads penetration of dextran into the membrane pore structure concurrently with drag permeation, which could not be easily cleaned by cross-flow filtration. Pore blocking due to dextran seems deteriorate with the elevation of ratio between dextran size and membrane pore size, even though higher hydrophilicity of the membrane is obtained (Aryanti *et al.* 2015, Susanto *et al.* 2007). The dextran flux profiles in Figure 4 show that the increase of PEG400 concentration enhances flux decline of the membrane.

The effect of PEG400 concentration of PVC membrane fouling is also evaluated by measuring flux recovery ratio (FRR) and total flux loss (R_t) of the membrane after two (2) hours of dextran

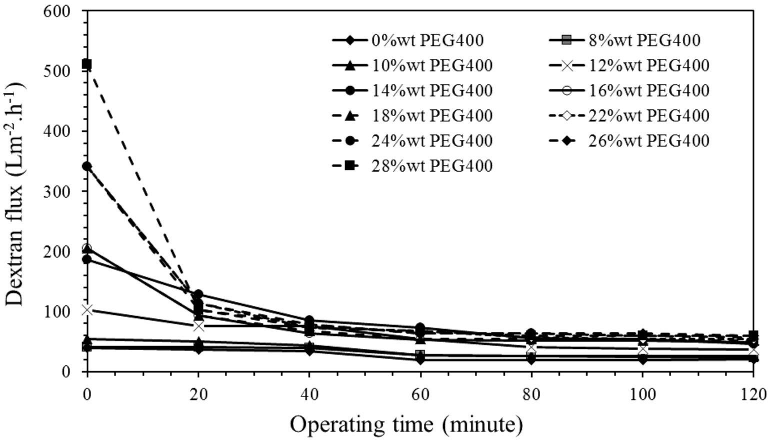


Fig. 4 Dextran flux profile during filtration period at 15 psig

filtration (Table 2). The FRR measurements are conducted to determine the cleaning efficiency of the membrane by comparing membrane flux between used and cleaned membrane. It shows that FRR is increased from 82 to 89% by the addition of 12 wt.% of PEG400. Meanwhile, over than 12 wt.% of PEG400, the FRR of resulted PVC membrane tends to decrease, which means that fouling resistance capability of the membrane is deteriorated.

High FRR value of the membrane indicates that most of fouling on the PVC membrane is reversible, which can be eliminated by simple cleaning, such as flushing method. It has been reported that the interaction between membrane surface and solute (dextran) could be weaken by improving hydrophilicity of the membrane and pore structure in the membrane skin layer (Susanto *et al*. 2007). In this research, the formation of larger pore by the addition of high concentration of PEG400 allows the relaxation of the solute gel layer on the membrane surface and further deposition on or inside of the gel layer as the increasing of contact time. A similar phenomenon had also been reported by Chen *et al*. (1997). High concentration of dextran onto the membrane surface generates initial irreversible fouling that is caused by diffusion into the membrane structure.

As shown in Table 2, low irreversible fouling is formed in the membrane structure when 12 wt.% of PEG400 is blended into PVC membrane solution. This low irreversible value may be attributed by a uniform pore structure in the membrane skin layer (Bellona *et al*. 2004, Wickramasinghe *et al*. 2009). The interaction between membrane surface and dextran is weakened due to tight pore size in the membrane skin layer, which easily swept during cross-flow filtration. Further increase of PEG400 content, larger pores are formed in the membrane structure that induces irreversible fouling and enhances total flux loss. Almost 90% of irreversible fouling is formed when the PEG400 concentration is raised from 24 to 28 wt.%. Irreversible fouling that have been blocked the membrane pore induces the formation of cake layer on the membrane surface (Miller *et al*. 2014). As the increase of PEG400 that produces more open pore in the membrane skin layer, flux becomes sufficiently high and the open pores become more quickly blocked by dextrans. On the other hand, porous membrane surface also plays an important role in

Table 2 Effect PEG400 content in casting solution to Flux Recovery Ratio (FRR) and Flux Loss due to fouling

PEG content (%wt)	FRR %	Reversible flux loss (*Rr*)	Irreversible flux loss (*Rir*)	Total flux loss (*Rt*)
0	82.26	0,313	0,177	0,490
8	85.64	0,357	0,144	0,501
10	89.23	0,602	0,108	0,710
12	89.55	0,681	0,104	0,785
14	84.62	0,596	0,154	0,750
16	70.00	0,533	0,3	0,833
18	34.44	0,189	0,655	0,844
22	27.27	0,115	0,727	0,842
24	10.42	0,022	0,839	0,861
26	9.52	0,008	0,877	0,885
28	6.00	0,005	0,907	0,912

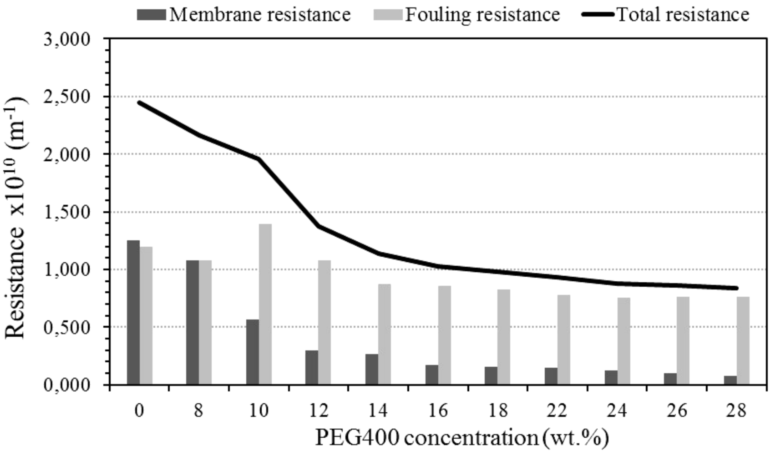


Fig. 5 Total resistance on the PVC membrane after two (2) hours of dextran filtration

membrane fouling (Woo *et al*. 2015, Zhong *et al*. 2012). As shown in Fig. 1(c), the agglomeration of entrapped PEG400 in membrane matrix is occurred when 28%wt of PEG400 is added into PVC membrane solution, thus the porous membrane surface becomes rougher. During the dextran filtration, solutes (dextrans) are preferentially transported into the valleys of roughness that quickly clog the valleys (Vrijenhoek *et al*. 2001). Hence, significant flux loss is resulted.

Fig. 5 shows the effect of PEG400 content on total resistance of fouled PVC membrane during dextran filtration. It is found that the increase of PEG400 concentration reduces the intrinsic membrane resistance continuously, but results in higher fouling resistance. The fouling resistance is attributed by concentration polarization of solutes on the membrane surface (Hwang and Sz 2010). Highest fouling resistance is resulted at the addition of 10%wt of PEG400. More accumulation of dextran on the membrane surface could be driven by the non-uniform of pore structure in the membrane skin layer and also hydrophobic interaction between PVC membrane and dextran molecules. Total fouling resistances is starting to reduce by the addition of 12 wt.% of PEG400 concentration. Meanwhile beyond 22 wt.% of PEG400, the fouling resistance reaches a plateau.

4. Conclusions

Preparation of PEG400 modified PVC membrane and evaluation on its characteristic have been conducted, by comparing the unmodified and PEG400 modified membrane. The presence of additive in PVC membrane solution changes the thermodynamic and kinetic characteristics during the formation of asymmetric membrane structure in coagulation bath. The presence of PEG400 contributes to higher diffusion rate of water into membrane solution, which forms macrovoid cavities in the bottom layer of PVC membrane. These macrovoid cavities could be suppressed by the addition of PEG400 into membrane solution. The increase of solution viscosity due to the presence of PEG400 prevents the growth of pore in membrane structure kinetically. On the other hand, the addition of 28 wt.% of PEG400 results in aggregation of entrapped PEG400 in the PVC membrane matrix, which contributes to rough surface on the membrane.

Unmodified membrane has low hydrophilic nature with a water contact angle (WCA) of 70°. The addition of 28 wt.% of PEG400 enhances the membrane hydrophilicity up to 80% compared with the unmodified membrane. Improvement in membrane hydrophilicity contributes to the improvement in pure water flux, but lower rejection of dextran. The lower rejection of dextran in high concentration of PEG400 is attributed by the formation of open pore in membrane skin layer. This open pore structure leads to higher irreversible fouling in membrane structure that induces by drag permeation. Beyond 22 wt.% of PEG400, a 90% of irreversible fouling was formed in the PVC membrane structure. As a consequence, low flux recovery ratio and plateau fouling resistance is resulted.

In this study, optimum result in ultrafiltration membrane performances is achieved when 12 wt.% of PEG400 is added into the PVC membrane solution. High water flux of 200 $Lm^{-2}h^{-1}$ and 90% rejection of dextran T-100 is achieved coupled with lower irreversible fouling resistance capability, which contribute to high flux recovery ratio.

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