MJIT 2022 Malaysian Journal of Industrial Technology

OBSERVATION OF PSF LOADING EFFECT ON DOUBLE LAYER SUBSTRATE STRUCTURE THROUGH SEM IMAGING

*H. Mustafa.
College of Engineering, Universiti Teknologi MARA Cawangan Johor, Kampus Pasir Gudang, Johor Bahru, Malaysia.
haikal4757@uitm.edu.my

S. F. Alfashni.
College of Engineering, Universiti Teknologi MARA Cawangan Johor, Kampus Pasir Gudang, Johor Bahru, Malaysia.
2019261576@isiswa.uitm.edu.my

N. F. M. Yusof.
College of Engineering, Universiti Teknologi MARA Cawangan Johor, Kampus Pasir Gudang, Johor Bahru, Malaysia.
farhanayusof@uitm.edu.my

N. H. Rahim.
College of Engineering, Universiti Teknologi MARA Cawangan Johor, Kampus Pasir Gudang, Johor Bahru, Malaysia.
norinhafizah@uitm.edu.my

N. H. Hanib.
College of Engineering, Universiti Teknologi MARA Cawangan Johor, Kampus Pasir Gudang, Johor Bahru, Malaysia.
hazwanihanib@uitm.edu.my

*Corresponding author's email: haikal4757@uitm.edu.my

ABSTRACT

The earth's surface is covered in water. However, not all water is safe for consumption. The best example would be seawater. Sea water consists of high concentrations of salt and could cause dehydration or in a worst-case scenario, death. The current method for converting seawater to drinkable water is seawater desalination. The relatively low cost, low energy consumption, short construction cycle, simple equipment and operation, and ease of management are all reasons why reverse osmosis (RO) is currently the most used desalination technology. From previous studies, hydrophilic nanoparticles, such as Silver (Ag), and Titanium Dioxide TiO2 were successfully incorporated. These nanoparticles have a considerable influence in terms of salt rejection and anti-fouling capabilities which will increase the water flux of the membrane, and fouling will be decreased, resulting in improved membrane performance. However, in previous studies, it was shown that high loading of nanoparticles will result in lower salt rejection performance. This happened due to the integrity of the membrane structure that is compromised by the agglomeration of nanoparticles. To further improve the structure of Psf substrate, application of double layer substrate is applied in fabrication. This is where a layer of dope solution is casted onto an existing solution. For this study, a first layer is fabricated by casting a dope solution consisting of 84.5% of N-methyl-2-pyrrolidone (NMP), 0.5% of polyvinylpyrrolidone (PVP), and 15% polysulfone (Psf). This dope solution will be the base layer for the double-layered substrates. In this study, 3 substrates with different concentrations of Psf, that are 5%, 10% and 15% are fabricated. From the SEM Imaging, it proves that this study was completed successfully, as the structure of the substrates fabricated, are like those of other researchers, which is a finger-like structure. However, due to the lack of experience in using a Scanning Electron Microscope (SEM) Imaging, a proper image of the double-layered substrate failed to be captured. Further studies need to be conducted to determine the effects of the double layer on the overall membrane performance.

Keywords: *Desalination; Polysulfone (Psf); Membrane; Reverse Osmosis, Double Layer*

1.0 Introduction

In research by Matt Williams, it is stated that water covers 71% of the Earth's surface while the remaining 29% is continents and islands. 96.5% of the earth's water is salt water, and the remaining water of 3.5% is freshwater [1]. Matt Williams also mentioned that 69% of the freshwater supply are frozen in glaciers and polar ice caps. The rest of the freshwater supply is stored in the soil, beneath the ground, in lakes, rivers and streams on the Earth's surface [2]. According to Abdel-Fatah and Al Bazedi, not all water is fresh or potable [3]. The water supply is considered limited as freshwater is used daily for multiple purposes. An article 8 years back shows that 42% of our freshwater usage is for agricultural uses, 39% of fresh water is used to produce electricity, 11% is for homes, offices, and hotels usage and the remaining 8% is for manufacturing and mining activities [2]. Chamhuri Siwar *et al*. [4] discovered that water demand in Malaysia for agricultural, industrial, and domestic activities steadily increased from 8.9 billion m3 in 1980 to 15.5 billion m3 in 2000. This shows that water availability per capita is diminishing. It was also discovered that the country's rural population has less access to fresh and clean water than the urban population. As a result, access to uncontaminated water is becoming a major concern for the water sector, with the main challenge being to reach the per capita water consumption target [4].

Water scarcity affects all continents. A major study in 2007 states that around 1.2 billion people, or nearly one-fifth of the global population, live in areas of physical scarcity, and another 500 million are on the verge of becoming so [5]. Another 1.6 billion people, or nearly a quarter of the global population, are affected by economic water scarcity due to a lack of infrastructure to extract water from rivers and aquifers [5]. Water usage has been growing as the rate of population increases in the last century. Although water scarcity is not global, an increasing number of regions are short of water at an alarming amount and a few others will soon face the same fate [6].

As stated in a World Water Development Report, March 2012, an area that has an annual water supply of 1700 cubic meters per person is said to be experiencing water stress, an area with an annual water supply of 1000 cubic meters per person is said to be experiencing water scarcity and an area with the annual water supply of 500 cubic meters per person is said to be experiencing "absolute scarcity" [7]. Water scarcity can mean scarcity due to physical storage or scarcity in access due to the failure of institution to ensure a regular supply or due to lack of infrastructure [7]. Water scarcity can be defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully [7]. Water scarcity will be exacerbated as rapidly growing urban areas place heavy pressure on neighbouring water resources. In a press release, on 18 March 2016, UN Secretary-General states that with the existing climate change scenario, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions by 2025 and almost half the world's population will be living in areas of high water stress by 2030, including between 75 million and 250 million people in Africa. In addition, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people [7].

South Africa is one of the world's 30 driest countries, having an annual rainfall of around 40% less than the global average. The average annual rainfall of South Africa is less than 500 mm, while the global average is around 850 mm [8]. This is nearly half the earth's average. Thus, South Africa is classified as a water-stressed country. Not only that, but South Africa's freshwater is decreasing in quality because of an increase in pollution and the destruction of river catchments, caused by urbanization, deforestation, damming of rivers, destruction of wetlands, industry, mining, agriculture, energy use and accidental water pollution [9].

Droughts and floods occur in South Africa on a regular basis, affecting the amount of water available throughout the country. Furthermore, hot, dry circumstances cause a high rate of evaporation [10]. A report in 2019 by Alexander [11], addressed Cape Town's issues regarding Cape Town's 'Day Zero' Water Crisis. After three consecutive years of anaemic rainfall, Cape town experienced a terrible drought in 2018 which they labelled day-zero. The countdown to day-zero was 90 days and the city with a population of up to 4 million people was 3 months away from running out of water. The population of South Africa will have to rely on salt water as a source of freshwater due to a decrease in freshwater supply.

Malaysia can somehow relate to this water issue in South Africa. A state in Malaysia, Selangor, has recorded the highest issues regarding water supply in 2018. According to a survey by the Malaysian Water Association, Selangor accounted for 49.5 % of all water supply concerns in Malaysia in 2016, and 62.4 % in 2017 [12]. One of the causes of water disruptions in Selangor, according to Datuk Seri Dr. Zaini Ujang, then-secretary general of the Energy, Green Technology and Water Ministry (KeTTHA), is that the state has very few treated water reserves. In the instance of Selangor, there is essentially no extra water because most of the water processed is used up, leaving no surplus. This, according to Dr. Zaini, is counter to best practice, which suggests at least a 10% reserve. By comparison, Penang had been quoted to have more than 30% in reserves [13]. Dr. Zaini continued saying that Selangor is rapidly developing, although the water supply and distribution system has been hardly modernised for several years. Burst pipes are common since the pipes were built when Selangor's water demand was lower, and they were not meant to manage the additional pressure. In 2017, Selangor used more water than the rest of Malaysia. While Selangor's per capita usage is like that of 1998, the population has expanded significantly since then [13]. Selangor may face the same fate as South Africa in years to come.

For humans, consuming salt water is not a safe water supply because it can cause dehydration. The main reason for this statement is because salt water contains a higher concentration of salt than the required amount of salt by our body and in fact higher than our body can handle. An article by Britannica [14], The Editors of Encyclopaedia, explains that after saltwater is consumed, the tissues shrink as dehydration proceeds, the skin gets dry and wrinkled, and the eyes become sunken and the eyeballs mushy. As dehydration worsens, a fever may develop, ranging from mild to severe. The temperature regulating centres in the brain are likely to be affected by dehydration. However, as dehydration and salt loss increase, plasma volume and cardiac output decrease, resulting in a reduction in blood flow to the skin. Sweating reduces and, in some cases, ceases entirely, and the primary route for heat loss is blocked. The body's temperature may then skyrocket. Last and least, the blood plasma volume varies. At the expense of tissue fluids, the plasma volume is maintained constant.

If, on the other hand, the plasma volume decreases, the heart's output decreases, and the pulse rate rises, all of which suggest a severe physical state. In humans, kidney changes develop because of dehydration. However, if water restriction continues and plasma volume decreases, urine output will be substantially reduced. When urine flow falls below 28 grams per hour, the kidneys are unable to function properly, the salt is retained in the body, and blood concentrations rise. The loss of 12 to 15 litres of bodily fluids causes mortality in a previously healthy adult. Death happens with a lower degree of dehydration among the very young, the very old, or the disabled. This is how dehydration happened to human's body after saltwater was consumed [14].

Due to this, there is some method and process used to make salt water drinkable. The first known desalination plant dates from the time of Thales of Miletus and Democritus [15], who stated that fresh water could be obtained by filtering seawater through the earth, and from the end of the first century (150-249) by the Greek physicist-mathematician Alejandro de Aphrodisias, who describes for the first time the process of distillation as a method of obtaining fresh water from seawater [15]. In his work Rosa medicinae, John Gaddesden referred to four procedures for desalinating sea water later in the Middle Ages [15]. The process is related to the osmosis phenomenon which also occurs in the human body.

Osmosis is a net spontaneous movement or diffusion of solvent molecules through a selectively permeable membrane from an area of high-water potential to an area of low water potential in a direction that tends to equalize the solute concentrations on both sides [16]. An area of high-water potential is an area with lower solute concentration and an area of low water potential is an area with higher solute concentration. It can also be used to describe a physical process in which each solvent migrates through a selectively permeable membrane, a membrane that is permeable to the solvent but not solute, that separates two solutions of different concentrations. Osmosis may be opposed by increasing the pressure in the region of high solute concentration with respect to that in the low solute concentration region. The force per unit area, or pressure, required to prevent the passage of water through a selectively permeable membrane and into a solution of greater concentration is equivalent to the osmotic pressure of the solution. Osmotic pressure is a colligative property, meaning that the property depends on the concentration of the solute, but not on its content or chemical identity [17].

The common way of treating seawater is by using membrane technology [18]. Membrane technology has a relatively low cost, low energy consumption, short construction cycle, and simple equipment and operation. A membrane is a thin sheet of natural and/or synthetic material which is usually supported by a fibrous network impermeable to substances in solution. Membrane desalination is hydrophobic, have little or no tendency to adsorb water and water tends to bead on its surfaces. Due to its hydrophobicity, membrane desalination is improvised to increase its efficiency in separating or distillate salt from salt water to produce portable water [19]. The process is related to the osmosis phenomenon which also occurs in the human body. After several years of improvement, an article from H. Lee *et al*. proposed the application of nanoparticles [20]. The application of nanoparticles in membrane desalination has been tested and it has been proven successful in improving the performance of desalination membranes [21].

2.0 Literature Review

2.1 Single Layered Psf Substrate

Membranes have risen to prominence in membrane research and are utilised in a wide range of applications due to their capacity to regulate the passage of pollutants in water and act as a selective barrier [22]. Polymeric membranes are made of natural or synthetic polymers and act as a selective interphase barrier between two solutions, allowing for more selective membrane transport [23]. The chemical nature, composition, porosity, and physical and chemical properties of the polymer all have an impact on the separation rate. Nanofillers are incorporated into the polymer matrix to improve barrier performance because polymer alone cannot efficiently transport liquid.

Reverse Osmosis (RO) membranes have been made using a variety of polymer materials, including cellulose acetate/cellulose triacetate, polyamide, polysulfone (Psf), and others. Various natural, synthetic, and inorganic polymers are employed in the manufacture of RO membranes. Fabrication of membranes with various types of polymers has offered membrane research a new perspective. Some methods for preparing polymer solutions for membrane production include solution casting, melting, and mechanical mixing.

The performance of a membrane is determined by its surface chemistry and morphology, surface modification has been demonstrated as a method for improving the membrane's performance, such as increasing its hydrophilicity, improving selectivity and flux, adjusting transport properties, and increasing its resistance to fouling on its surface [22]. Fouling-free membranes and increased penetration flux, particularly in water, can be achieved by covering the surface of a hydrophobic support membrane with a hydrophilic membrane. A thin film composite (TFC) is an asymmetric membrane that consists of a porosity nonselective support membrane layer and a thin layer of the dense typed membrane. TFC can be made in a variety of ways, including lamination, which involves casting a dense thin layer of membrane onto a casted porous support membrane, interfacial polymerization, and dip coating of a polymer solution onto the porous support membrane, followed by drying of the coated layer. The presence of a thin film-dense layer is functions as a barrier or selective layer for the selective removal of the required particles [24].

The membrane material employed in a study by Emadzadeh D. *et al.* [25], shows that it is made up of polymer, solvent, and an additive. Polysulfone (Psf) is the polymer employed in this study to create a nanofiltration flat sheet membrane. Psf was chosen as the primary component due to its properties and benefits. The outstanding balance of chemical, thermal, and mechanical properties, Psf is commonly employed as a component in membrane construction. Furthermore, it has strong chemical and thermal stability up to 80 °C, as well as a pH range of 1.5 to 12 for cleaning. Despite showing some resilience to oxidising chemicals such as chlorine and the ability to retain mechanical characteristics in hot and moist situations. N-methyl-2-pyrolidon (NMP) was utilised to make the dope solution. NMP was chosen as a solvent since it can dissolve in a variety of polymers. When immersed in water, the casting solution based on this solvent can precipitate rapidly, resulting in porous and highly anisotropic membranes. To increase the properties of polymer membranes, an additive is added to the polymer solution. Polyvinylpyrrolidone (PVP) was the additive employed in this investigation.

According to Yoo *et al.* adding the second polymer to the solution produced high porous membranes, well-interconnected pores, and surface properties [3]. PVP was chosen because of its advantages. The PVP will regulate morphogenesis in terms of both thermodynamics and kinetics. As a result, it makes the system unstable and prone to phase separation thermodynamically. In kinetics, the high viscosity of the polymer solution after the addition of PVP will delay phase separation and slow down the demixing process.

2.2 DOUBLE LAYERED PSF SUBSTRATE

Jie Li *et al.* shows that the pore sizes and surface hydrophilicity of the substrate have an impact on the composite membranes' RO performance [26]. A study by Lim *et al.* also shows that the dual-layered thin-film composite TFC Polysulfone/Graphene Oxide membrane (TFC-PsfdGO) exhibited high water permeability [27]. Nanoparticles are applied in the fabrication of the substrate to improve its performance. A nanoparticle has a hydrophilic property and therefore will allow more water to pass through the membrane [22]. However, the downside of using nanoparticles is that they tend to agglomerate and compromise the structure of the membrane. This phenomenon is further explained by H. Duong *et al*., which state that the agglomeration of nanoparticles happens due to the adhesion of particles to each other by weak forces which leads to micronized entities [28]. The study by Lim *et al.* [27] brought about an experiment applied in this study which uses the idea of a dual-layered membrane. An application of double-layered membrane was applied to overcome the issues regarding the agglomeration in nanoparticle membranes. Two layers of the solution are casted on top of each other before being immersed in the bath for 24 hours. The first layer that was casted with a dope solution consisting of 15% of Psf. Figure 1 below shows the expected result of a dual-layered membrane [29].

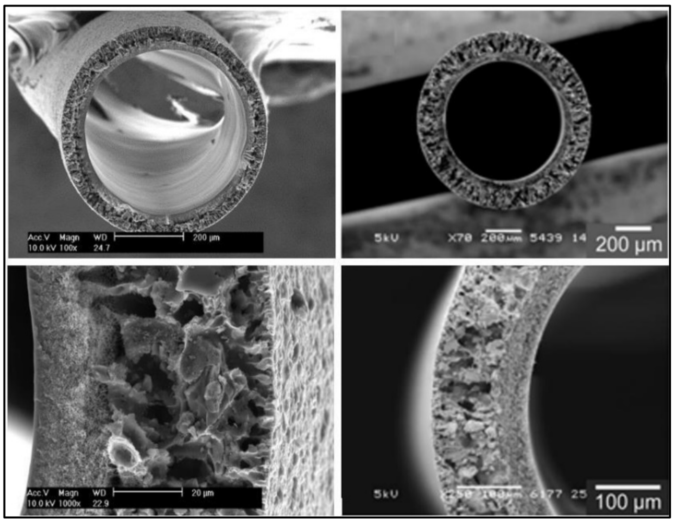


Figure 1. SEM images of dual layer membrane [29].

2.3 Problem Statement

Seawater can be converted into portable water through the seawater desalination process. The reliability and relatively low-cost are reasons why membrane desalination is currently the most used desalination technology. To further improve the performance of the membrane, the use of nanoparticles is applied in this technology. However, nanoparticles tend to agglomerate, compromising the structure of the membrane, which reduces salt rejection in the membrane. In this study, the use of double layer Psf substrate is proposed to mitigate the problem.

A hypothesis was made in this study. The higher the Psf content, the smaller the pores in the substrate and the structure is even more packed. This hypothesis was tested by applying different concentrations of Psf in each sample. The results in this experiment were obtained from the fabrication of Psf substrate and scanning electronic microscopy (SEM) analysis. The difference in the structure for each substrate will be observed, studied, and recorded.

As mentioned previously, reverse osmosis is used in the desalination process. A thin film composite (TFC) membrane is used in reverse osmosis. The nature of a TFC is to be hydrophobic to increase salt rejection. TFC consists of a polysulfone (Psf) layer and a polyamide (PA) layer. Polysulfone is a hydrophobic polymer, but the surface modification of hydrophobic polymers makes them hydrophilic [30]. In the fabrication of the Polysulfone (Psf) layer, nanoparticles, Silver (Ag), and Titanium Dioxide TiO_2 are incorporated.

Because of the high hydrophilicity characteristics, these nanoparticles have a considerable influence in terms of salt rejection and anti-fouling capabilities. A journal by Park *et al*. states that water flux of the membrane will be increased, and fouling will be decreased, resulting in improved membrane performance [31].

However, because the substrate's integrity has been compromised, these nanoparticles agglomerate, reducing salt rejection. To further improve the structure of Psf substrate, an application of double layer is applied in fabricating this substrate. The first layer is fabricated by casting a dope solution consisting of 84.5% of N-methyl-2-pyrrolidone (NMP), 0.5% of polyvinylpyrrolidone (PVP), and 15% polysulfone (Psf). This dope solution will be the base layer for all double-layered substrates.

In this study, the research by Lim *et al*. [27] will be replicated using 3 samples, with the exception that the Psf content in each sample will be manipulated. The Psf concentration that will be used are 5%, 10%, 15% and the structure of the double layer Psf substrate will be observed.

The objective of this study is to fabricate three double-layered Psf substrates and observe the fabricated structure through Scanning Electron Microscope (SEM) imaging.

3.0 Methodology

In order to conduct the experiment, a study by Safarpour *et al*. [32], and Xia *et al*. [33], were used as references for dope preparation, membrane casting and membrane testing. Membrane manufacture entails several steps as shown in Figure 2.

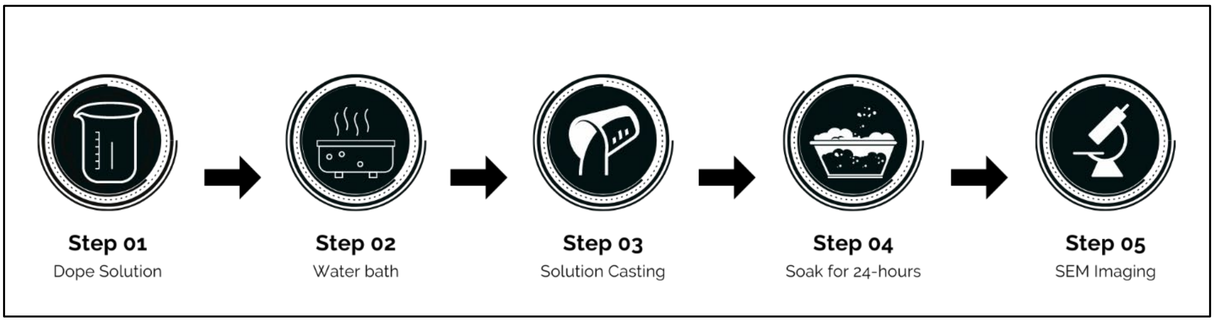


Figure 2. Steps in membrane manufacturing.

3.1 Materials

The materials used were prepared based on the works of Gao *et al*. [34], Wu *et al*. [35] and Zhao *et al*. [36]. Polysulfone (Psf), polyvinylpyrrolidone (PVP), N-methyl-2-pyrrolidone (NMP), titanium dioxide (TiO2) and silver (Ag) were used to prepare a dope solution.

3.2 Dope Preparation

Safarpour *et al*. work was consulted to produce dope solution [37]. A base solution with the weights of Psf, PVP, NMP, at 15 wt%, 0.5 wt%, and 84.5 wt%, respectively is applied in preparing a double-layered Psf substrate. Psf, PVP, and NMP were mixed in a 250ml glass bottle. The NMP and PVP mixture are then mixed with a magnetic stirrer for 20 minutes. After that, half of the Psf was poured in and stirred for 30 minutes. The remaining Psf was then poured into the glass bottle and stirred continuously for another 24 hours at room temperature. The solution is then immersed in a water bath for 30 minutes. The substrate layer was cast by pouring the dope solution onto a glass plane and rolling it down with a glass rod. The glass plane was immediately soaked in a bowl of tap water after the support layer was cast.

3.3 PSF Double Layered Substrate Membrane Casting

In addition to the procedure stated above, the previous layer was framed with duct tape as support before a dope solution from sample 1 was poured onto the previous layer and was rolled down with a glass rod before it was soaked into the basin of tap water. This procedure is repeated with samples 2 and sample 3. Figure 3 shows the arrangement of material used in fabricating double layer membranes at different Psf concentrations.

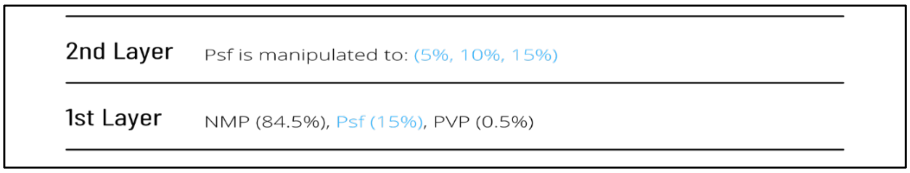


Figure 3. Illustration of fabricated double layer membrane at different Psf concentrations.

Table 1 below is referred to in producing 3 different substrates. These samples then go through a soaking and drying process for 24 hours.

Table 1. Composition of dope solution for Psf substrate double layer.

Sample	Chemical substance/solid	Composition (%)	Quantity (g or ml)
	NMP	94.5	91.7 ml
1	PVP	0.5	0.5 g
	Psf	5	5 g
	NMP	89.5	86.9 ml
2	PVP	0.5	0.5 g
	Psf	10	10 g
	NMP	84.5	82.1 ml
3	PVP	0.5	0.5 g
	Psf	15	15 g

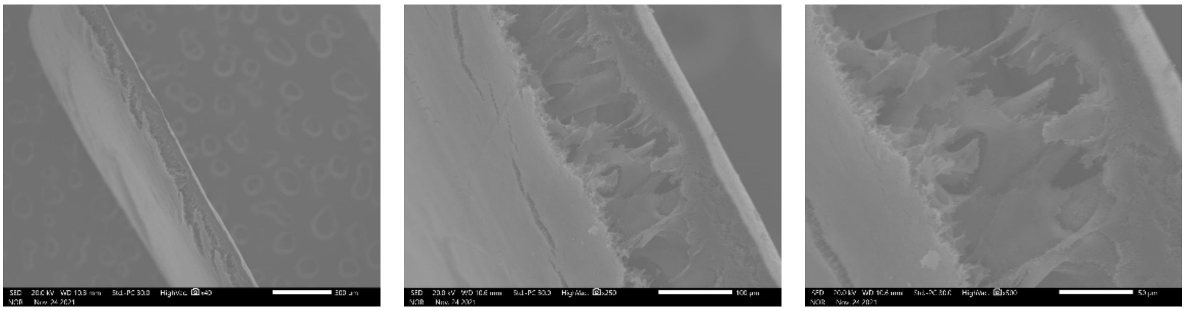
3.4 SCANNING ELECTRON MICROSCOPE (SEM) IMAGING

The substrates are then cut up into a small square piece (1cm x 1cm) and placed onto the specimen stage. The excess dust is blown by a blower and coated with gold. It is then placed in the SEM machine for Imaging.

4.0 Result and Discussion

4.1 Results

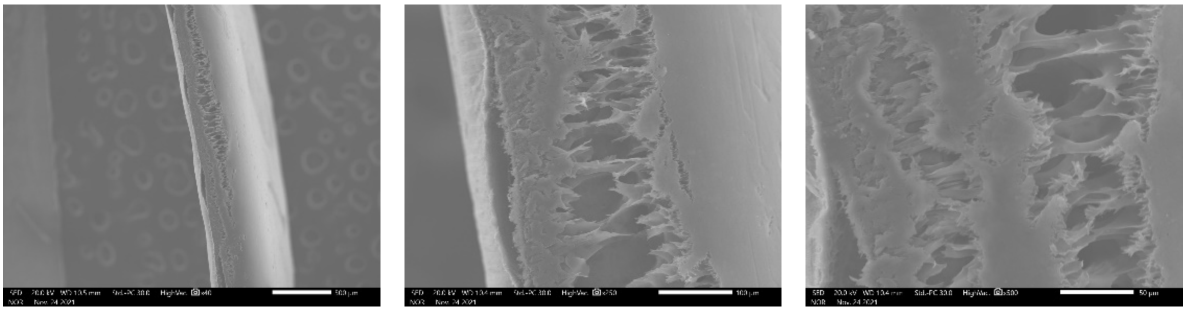
Results show the structure of 3 double layer Psf substrate with different magnification which is 40x, 250x and 500x per sample. The images viewed are the cross-sectional area of the substrate. Figure 4 shows the structure of a double-layer Psf substrate in which the first layer consists of 15% Psf composition, and the second layer consists of 5% Psf composition. The structure of each layer is different as the area of pores in the second layer is much larger than the first layer. Referring to Figures 4 (a) and (b), the pores of the first layer are unclear.



(a) (b) (c)

Figure 4. SEM imaging of Psf substrate double layer 5% wt. polysulfone at magnification (a) 40x, (b) 250x and (c) 500x.

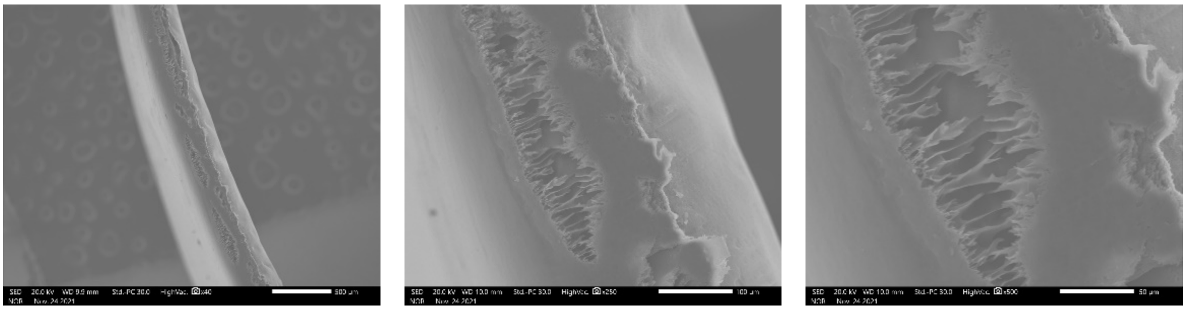
Figure 5 shows the pore structure of a double-layer Psf substrate containing 10% Psf composition in its second layer. Both layers can be seen clearly in Figure 5(c).



(a) (b) (c)

Figure 5. SEM imaging of Psf substrate double layer 10% wt. polysulfone at magnification (a) 40x, (b) 250x and (c) 500x.

Figure 6 shows the structure of the cross-section of a double-layer Psf substrate containing 15% Psf composition in its second layer. Both layers have the same composition of Psf. However, in these images, the second layer of the substrate cannot be seen.



(a) (b) (c)

Figure 6. SEM imaging of Psf substrate double layer 15% wt. polysulfone at magnification (a) 40x, (b) 250x and (c) 500x.

3.2 Discussions

From Figure 4(c), the structure of the substrate is clearly shown that the substrate fabricated achieved a finger-like structure due to the presence of a thin film composite (TFC). The finding is similar to the research conducted by Lim *et al*. [27]. However, in this figure the composition of Psf is at 5%, and the structure shows larger pore areas compared to the previous research mentioned. The areas circled in Figure 7 show the difference in the pore sizes between the two substrates.

Figure 7 shows a comparison micrograph structure between images taken from this study and previous research. Figure 7(a)(c)(e) illustrates a finger-like structure that produced from a double layer membrane fabricated at 5%, 10% and 15% Psf respectively. While a sponge-like structure was reported from various research were shown in Figure 7(b)(d)(f) as retrieved from Lim *et al*. [27]

The figures above show that the different concentration of Psf in the substrate influences the structure and porosity of the substrate. According to D. Ariono *et al*., in low polysulfone concentrations, the substrate would have a larger pore size and the retention of low molecular weight solutes accumulated on the membrane surface is lower than the intrinsic membrane resistance [38]. However, the solute will easily pass through the membrane which will lead to low rejection of humic substances [38].

What we can infer from the results obtained is that the unclear image in Figure 4 may be caused by the wrong positioning of the substrate in the preparation for the SEM imaging. This is because when the substrate is positioned in the wrong way, the structure for both layers is crooked and therefore cannot be captured by the SEM machine.

In Figure 5, it can be seen that the first layer consisting of 15% Psf has a smaller pore area compared to the second layer consisting of 10% Psf. Based on the hypothesis, the higher the Psf content, the smaller the pores in the substrate and the structure is even more packed. This result shows that the finger-like structure of the substrate with a lower concentration has a larger pore area as it is less packed compared to the substrate with a higher concentration.

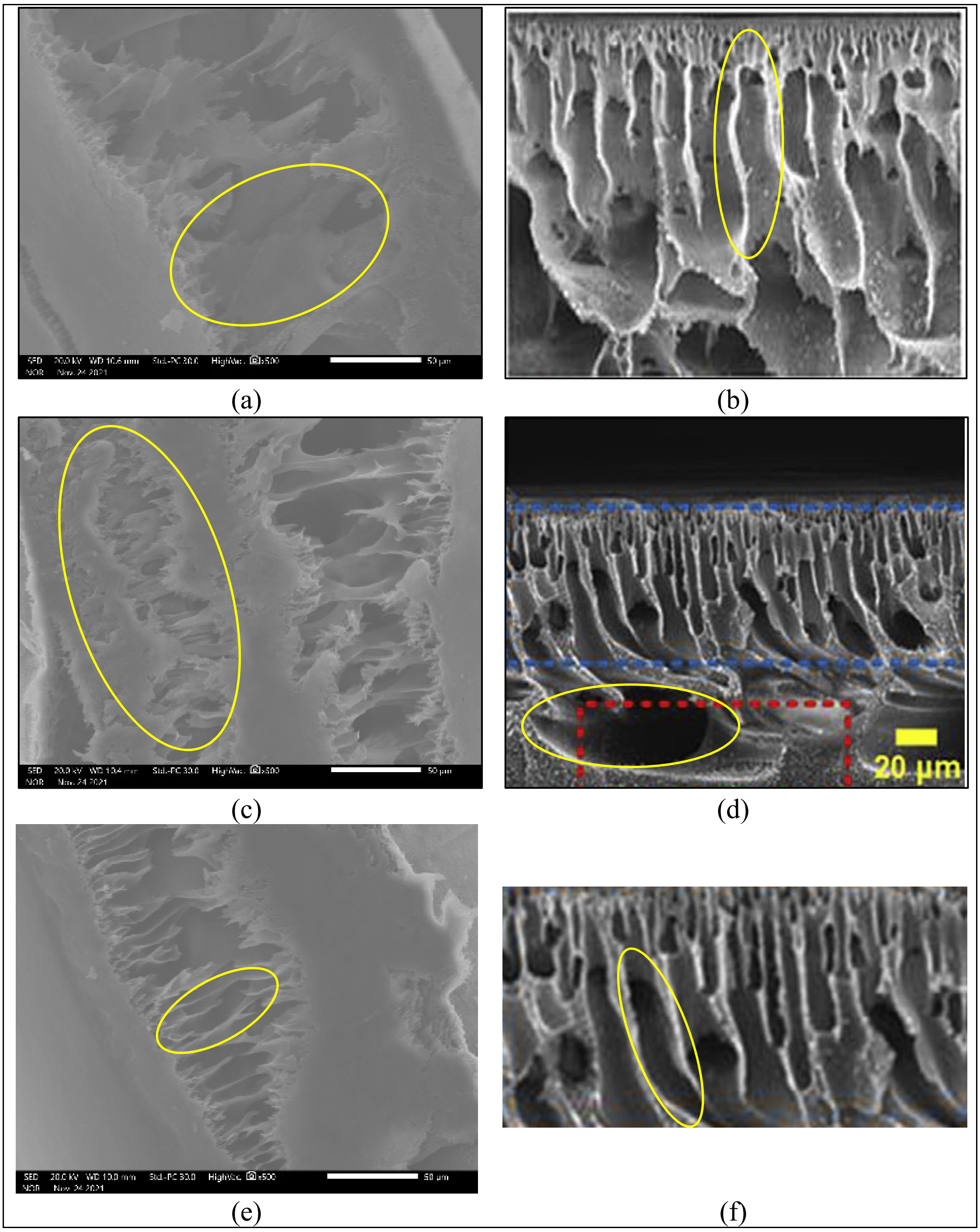
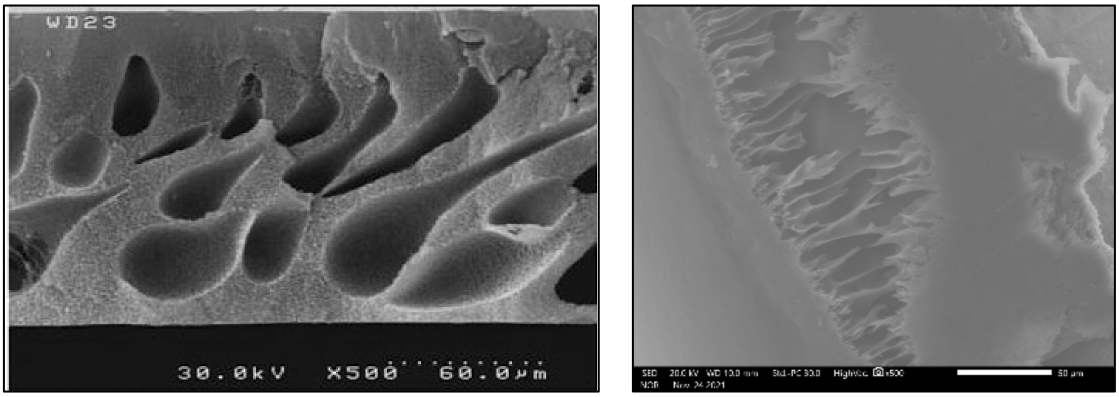


Figure 7. Micrograph images of substrate at (a) 5% Psf, (c) 10% Psf, (e) 15% Psf and (b), (d), (f) are images taken from the previous study at 15% Psf substrate.

In Figure 7(e) and Figure 7(f), the concentrations of both first and second substrates are equal. This means that the structure and porosity of the substrate should be the same. But in Figure 6 (c), the magnification is only focused on the first layer of the substrate. It is believed that, like in Figure 4, this substrate was positioned poorly.



(a) (b)

Figure 8. A cross-section of (a) pure Psf membrane by Shahrokh *et al*. [39] and (b) a double layer Psf substrate containing 15% Psf composition.

Figure 8 shows the comparison of two cross sections. Figure 7(a) is a cross-section of a pure Psf membrane by Shahrokh *et al*. [39]. Figure 8(b) shows the cross-section of double layer Psf substrate containing of 15% Psf composition. From this comparison, it can be inferred that this research has been conducted successfully and was able to replicate the finger-like structure, like the expected results. Even with poor imaging, the objectives were successfully met which is to fabricate a double layer Psf substrate and observe the substrate. Further modifications can be made to improve the result of imaging such as positioning the substrates horizontally so that both layers can be seen clearly. For better results, the fabrication process should be done by following the exact composition of the substrate so that the polymerization occurs perfectly. Besides that, all the results of these substrates can be improved by placing the substrate straight at the sampling site. In addition, when placing the substrate on the sample plate, all samples should be placed horizontally to better recognize the position of the layers in the image captured.

4.0 Conclusion

In conclusion from this experiment, the objectives were successfully met. The Psf double layer substrate was fabricated and from the observations, the fabrication of the substrate was similar to another research. However due to the error in SEM imaging, in future studies, this error should be improved, and such recommendations have been mentioned in the discussion. For significant research, it is recommended to perform water permeating testing to determine the effects of the double layer substrate on the overall performance of the membrane.

5.0 Acknowledgement

Appreciation to the research team and technical staff of College of Engineering, Universiti Teknologi MARA Cawangan Johor, Kampus Pasir Gudang for providing support in the completion of this research.

6.0 References

[1] M. Williams, “What percent of Earth is water ?,” no. December, pp. 10–12, 2014.

[2] F. Ahmed, C. Siwar, and R. A. Begum, "Water resources in Malaysia: Issues and challenges," *Journal of Food, Agriculture and Environment*, vol. 12, no. 2, pp. 1100–1104, 2014.

[3] M. M. Amin Abdel-Fatah and G. Ahmed Al Bazedi, "Water Treatment and Desalination," in *Desalination - Challenges and Opportunities*, 2020. doi: 10.5772/intechopen.91471.

[4] F. Ahmed, S. Chamhuri, and R. A. Begun, "Water resources in Malaysia: Issues and challenges," 2014. https://www.researchgate.net/publication/287929596_Water_resources_in_Malaysia_Issues_and_challenges (accessed Feb. 12, 2022).

[5] D. (David) Molden, International Water Management Institute., and Comprehensive Assessment of Water Management in Agriculture (Program), *Water for food, water for life : a comprehensive assessment of water management in agriculture*. Earthscan, 2007.

[6] United Nations Development Programme., *Human development report 2006 : beyond scarcity : power, poverty and the global water crisis*. Palgrave Macmillan, 2006.

[7] (UNDESA) United Nations Department of Economic and Social Affairs, "International Decade for Action 'Water for Life' 2005-2015. Focus Areas: Water scarcity," 2014.

[8] Department of Communication and Information System, "National water security | South African Government," 2020. https://www.gov.za/speeches/national-water-security-13-nov-2015-0000 (accessed Jan. 19, 2022).

[9] Rand Water, "Water Pollution," 2017. https://www.randwater.co.za/CorporateResponsibility/WWE/Pages/WaterPollution.aspx (accessed Jan. 19, 2022).

[10] Rand Water, "Water Wise - Water Situation in South Africa." http://www.waterwise.co.za/site/water/environment/situation.html (accessed Jan. 19, 2022).

[11] C. Alexander, "Looking Back on Cape Town's Drought and 'Day Zero' - Bloomberg," 2019. https://www.bloomberg.com/news/articles/2019-04-12/looking-back-on-cape-town-s-drought-and-day-zero (accessed Feb. 12, 2022).

[12] S. Aznam Shah, "More than Splash's RM2.6b deal needed to end Selangor water crisis," 2018. https://themalaysianreserve.com/2018/09/24/more-than-splashs-rm2-6b-deal-needed-to-end-selangor-water-crisis/ (accessed Jan. 19, 2022).

[13] Badd, "Why is Selangor still suffering from water supply disruptions, even after 10 years?," 2020. https://cilisos.my/why-is-selangor-still-suffering-from-water-supply-disruptions-even-after-10-years/ (accessed Jan. 19, 2022).

[14] K. Rogers, "dehydration | physiology | Britannica." https://www.britannica.com/science/dehydration-physiology (accessed Jan. 19, 2022).

[15] "Desalinization of water, invention of man to survive - 4th International Conference and Exhibition Desalination Latin America." https://desalinationlatinamerica.com/desalinization-of-water-invention-of-man-to-survive/ (accessed Feb. 12, 2022).

[16] M. Zaccaria, M. Neri, F. Garzotto, and C. Ronco, "Principles of Extracorporeal Circulation and Transport Phenomena," in *Critical Care Nephrology: Third Edition*, 2019. doi: 10.1016/B978-0-323-44942-7.00139-4.

[17] J. Feher, "Quantitative Human Physiology: An Introduction," in *The American Journal of the Medical Sciences*, vol. 243, no. 4, 2012.

[18] H. Zhang, "Application of silver nanoparticles in drinking water purification," *Open Acces Dissertations*, p. Paper 29, 2013, [Online]. Available: http://digitalcommons.uri.edu/cgi/viewcontent.cgi?article=1033&context=oa_diss#page=124

[19] T. Peters, "Membrane technology for water treatment," *Chemical Engineering and Technology*, vol. 33, no. 8. pp. 1233–1240, Aug. 2010. doi: 10.1002/ceat.201000139.

[20] S.-H. Park, S. Kim, D.-J. Lee, S. Yun, Z. G. Khim, and K.-B. Kim, "Selective Wet-Chemical Etching of the Barrier Layer during Formation of Porous Anodic Aluminum Oxide Template," *Journal of The Electrochemical Society*, vol. 156, no. 11, p. K181, 2009, doi: 10.1149/1.3207011.

[21] N. Ghasem, M. Al-Marzouqi, and A. Duidar, "Effect of PVDF concentration on the morphology and performance of hollow fiber membrane employed as gas-liquid membrane contactor for CO 2 absorption," *Separation and Purification Technology*, vol. 98, pp. 174–185, Sep. 2012, doi: 10.1016/j.seppur.2012.06.036.

[22] T. Peters, "Membrane technology for water treatment," *Chemical Engineering and Technology*, vol. 33, no. 8, pp. 1233–1240, 2010, doi: 10.1002/ceat.201000139.

[23] F. and A. Organization, "Coping with Water Scarcity. Challenge of the 21st Century," *Japanese Journal of Radiological Technology*, vol. 52, no. 6, p. 794, 1996, doi: 10.6009/jjrt.KJ00001354487.

[24] S. Park, S. Kim, D. Lee, S. Yun, Z. G. Khim, and K. Kim, "Selective Wet-Chemical Etching of the Barrier Layer during Formation of Porous Anodic Aluminum Oxide Template," *Journal of The Electrochemical Society*, vol. 156, no. 11, p. K181, 2009, doi: 10.1149/1.3207011.

[25] N. Ghasem, M. Al-Marzouqi, and A. Duidar, "Effect of PVDF concentration on the morphology and performance of hollow fiber membrane employed as gas–liquid membrane contactor for CO_2 absorption," *Separation and Purification Technology*, vol. 98, pp. 174–185, Sep. 2012, doi: 10.1016/j.seppur.2012.06.036.

[26] X. Li, Q. Li, W. Fang, R. Wang, and W. Krantz, "Effect of the support on the characteristics and permselectivity of thin film composite membranes," *Journal of Membrane Science*, vol. 580, Mar. 2019, doi: 10.1016/j.memsci.2019.03.003.

[27] *et al.*, "Dual-layered nanocomposite membrane incorporating graphene oxide and halloysite nanotube for high osmotic power density and fouling resistance," *Journal of Membrane Science*, vol. 564, Jun. 2018, doi: 10.1016/j.memsci.2018.06.055.

[28] H. C. Duong *et al.*, "Membrane Distillation for Strategic Water Treatment Applications: Opportunities, Challenges, and Current Status," *Current Pollution Reports*, vol. 6, no. 3, pp. 173–187, 2020, doi: 10.1007/s40726-020-00150-8.

[29] "SEM images of fabricated dual-layer membranes (right-hand side images... | Download Scientific Diagram." https://www.researchgate.net/figure/SEM-images-of-fabricated-dual-layer-membranes-right-hand-side-images-are-adapted-from_fig1_319436744 (accessed Feb. 13, 2022).

[30] H. Lutz, "Ultrafiltration: Fundamentals and Engineering," *Comprehensive Membrane Science and Engineering*, vol. 2, pp. 115–139, Jan. 2010, doi: 10.1016/B978-0-08-093250-7.00037-2.

[31] M. Enfrin, J. Lee, A. G. Fane, and L. F. Dumée, "Science of the Total Environment Mitigation of membrane particulate fouling by nano / microplastics via physical cleaning strategies," *Science of the Total Environment*, vol. 788, p. 147689, 2021, doi: 10.1016/j.scitotenv.2021.147689.

[32] M. Safarpour, A. Khataee, and V. Vatanpour, "Effect of reduced graphene oxide/TiO2 nanocomposite with different molar ratios on the performance of PVDF ultrafiltration membranes," *Separation and purification technology*, vol. 140, pp. 32–42, 2015, doi: 10.1016/j.seppur.2014.11.010.

[33] H.-M. Chang *et al.*, "Innovative upflow anaerobic sludge osmotic membrane bioreactor for wastewater treatment," *Bioresource Technology*, vol. 287, p. 121466, 2019, doi: https://doi.org/10.1016/j.biortech.2019.121466.

[34] J. Ma, D. Ping, and X. Dong, "Recent Developments of Graphene Oxide-Based Membranes : A Review," 2017, doi: 10.3390/membranes7030052.

[35] B. Wu *et al.*, "Gravity-driven microfiltration pretreatment for reverse osmosis (RO) seawater desalination: Microbial community characterization and RO performance," *Desalination*, vol. 418, pp. 1–8, May 2017, doi: 10.1016/j.desal.2017.05.024.

[36] S. Zhao and L. Zou, "Effects of working temperature on separation performance, membrane scaling and cleaning in forward osmosis desalination," *Desalination*, vol. 278, pp. 157–164, Sep. 2011, doi: 10.1016/j.desal.2011.05.018.

[37] M. Safarpour, A. Khataee, and V. Vatanpour, "Effect of reduced graphene oxide/TiO2 nanocomposite with different molar ratios on the performance of PVDF ultrafiltration membranes," *Separation and Purification Technology*, vol. 140, pp. 32–42, Jan. 2015, doi: 10.1016/j.seppur.2014.11.010.

[38] D. Ariono, P. T. P. Aryanti, S. Subagjo, and I. G. Wenten, "The effect of polymer concentration on flux stability of polysulfone membrane The Effect of Polymer

Concentration on Flux Stability of Polysulfone Membrane," vol. 030048, no. January 2017, 2018, doi: 10.1063/1.4968301.

[39] "Cross-section morphologies FE-SEM images of the prepared membranes. a... | Download Scientific Diagram." https://www.researchgate.net/figure/Cross-section-morphologies-FE-SEM-images-of-the-prepared-membranes-a-Pure-PSF-b_fig8_281226587 (accessed Feb. 13, 2022).

[40] I. Birsan, S. C. Pintilie, L. G. Pintilie, A. L. Lazar, A. Circiumaru, and S. Balta, "New Understanding of the Difference in Filtration Performance between Anatase and Rutile TiO 2 Nanoparticles through Blending into Ultrafiltration PSF Membranes," 2021.