Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Banana Peels Pectin Templated Silica Ultrafiltration Membrane in Disk Plate Configuration Applied for Wetland Water Treatment

Muthia Elma[1,2,3,*], Rhafiq Abdul Ghani[1,2], Aulia Rahma[2,3], Alya Dita Alyanti[2,4], Novrian Dony[5]

[1] Chemical Engineering Department, Faculty of Engineering, Lambung Mangkurat University, Banjarbaru, Indonesia
[2] Material and Membrane Research Group (M2ReG), Faculty of Engineering, Lambung Mangkurat University, Banjarbaru, Indonesia
[3] Environmental Science Doctoral and Postgraduate Program, Lambung Mangkurat University, Banjarbaru, Indonesia
[4] Environmental Engineering Department, Faculty of Engineering, Lambung Mangkurat University, Banjarbaru, Indonesia
[5] Chemistry Education, Islamic University of Kalimantan MAB Banjarmasin, Indonesia

ARTICLE INFO

Article history:
Received 10 April 2022
Received in revised form 30 August 2022
Accepted 12 September 2022
Available online 4 October 2022

ABSTRACT

South Kalimantan has natural surface water such as wetland water which easily found to prevent water scarcity. Two types of wetland water provided in tropical area i.e. (1) peat water which located in land area; and (2) wetland saline water that area is near to coastal zone. Both are unsuitable for consumption and required to be treated. Ultrafiltration (UF) is one of methods that can be applied for treating natural wetland water using silica membrane. However, it needs improved by carbon due to lacking its low hydrostability properties. This works investigated performance of banana pectin templated silica ultrafiltration membrane in varied operation pressure and feed water treatment. Preparation of ultrafiltration membrane was used banana peels pectin as carbon source that templated into silica sol through sol gel process. Silica pectin xerogel was characterized by Fourier Transformed Infra-red (FTIR) and morphology of silica pectin membrane was characterized by Scanning Electron Microscopy (SEM). The sol is carried out by a coating process to the alumina membrane support on 4 layers. The calcination process is using the Conventional Thermal Processing (CTP) method. Furthermore, the ultrafiltration process run on the dead-end ultrafiltration silica pectin membrane has three functional groups, namely siloxane (Si-O-Si) at a wavelength of 1061 cm^{-1}. silanol (Si-OH) at a wavelength of 966 cm^{-1} and silica carbon (Si-C) at a wavelength of 795 cm^{-1}. The performance of silica pectin membranes at pressures of 0.5 bar, 1 bar and 1.5 bar in peat water resulted in fluxes of 5.07 $kg.m^{-2}.h^{-1}$, 11.31 $kg.m^{-2}.h^{-1}$ and 18.90 $kg.m^{-2}.h^{-1}$ with rejection of organic matter of 85.56%, 85.49% and 84.68%. Meanwhile in wetland saline water it was 7.04 $kg.m^{-2}.h^{-1}$, 11.73 $kg.m^{-2}.h^{-1}$ and 20.52 $kg.m^{-2}.h^{-1}$ with rejection of organic matter of 82.50%, 79.46% and 78.11%. Salt rejection for wetland saline water for 0.5 bar until 1.5 bar is 84.39%, 82.54% and 81.04%. Ultrafiltration It can be concluded that the increase in pressure affects the performance of the silica pectin membrane where the flux value increases with each increase in pressure, but the rejection value of organic matter and salt rejection show a decreasing.

Keywords:
Wetland saline water; peat water; banana peels pectin; silica membrane; ultrafiltration; dead end

---

[*] *Corresponding author.*
E-mail address: melma@ulm.ac.id

https://doi.org/10.37934/arfmts.100.1.7788

1. Introduction

Water scarcity is a serious global issue that is getting critical by increasing population of people, industry, and agricultural which bring out the freshwater source could be disappearing [1]. Water is known as essential for the survival of mankind [2]. 2.7 billion people are suffering from water scarcity problems and still growing up [3]. The World Health Organization (WHO) also said there is more than 15% of the world's population does not have access to drinking water [4]. Drinking water problems has been encountered many regions in Indonesia due to different geographical and demographic characteristic [5].

South Kalimantan is located in the souths part of Kalimantan island-Indonesia that considerable found of wetland with height of soil at 0.16 m under sea level [6]. It is important in hydrology and big potential as water reservoir [7]. South Kalimantan has an abundant source of water especially wetland water [8]. However, Wetland water has poor qualities and not suitable for any consumption. Generally, the wetland water has brown in colour, low pH, and contain of natural organic matter (NOM) [9]. So, this wetland water is big source of clean water requires for contaminant removal process [7].

Membrane technology has long been a separation process in the industrial world because of its fast and efficient process [10-28]. In general, there are three types of membrane process that are usually applied, it is called reverse osmosis (RO), membrane distillation (MD), pervaporation and ultrafiltration [28]. Among various water treatment technologies, ultrafiltration (UF) is an alternative technology to improve water quality [26]. UF is a promising and the most widely applied technology for producing water consumption from surface water with a lower cost [29]. Besides, membranes UF has ease of fabrication and simple operation system [30]. Compared to reverse osmosis (RO) membrane, a UF membrane is operated by using lower operating pressure to retain solutes. The range of 1-10 bars is typical operating pressure for UF [31].

Membrane fabrication frequently applied mesopores silica in water separation. Silica has good mechanical strength and thermal stability [1]. In order to increase hydro stability and silica matrices endurance for mechanical and chemical strength, it is required a modification process on pure silica matrix by adding and templating carbon silica [26,32-42]. In addition, embedding carbon molecules into silica matrix lead well hydro stability of silica [43]. This carbon source may employ pectin [36]. Pectin can be extracted from banana peels (around 24,8 wt.%) [23,44].

As a great potential, pectin as carbon templated has promised excellent membrane performance. Previous work has been demonstrated silica pectin membrane has the great performance than silica P-123 membrane by pervaporation [45]. Elma *et al.,* [44] also reported 0.5 wt.% pectin concentration has better performance than 0.1 wt.% concentration when applied for desalination of wetland saline water and acid mine drainage. Therefore, this work investigates banana peels templated silica pectin performance on wetland water by ultrafiltration.

2. Methodology

2.1 Chemical and Materials

The natural feed water is implemented for the UF experiment in this work included peatland water and wetland saline water. Peatland water is taken from Sukamaju Village at Banjarbaru (3°23'57.6"S 114°43'09.0"E), whereas, the wetland saline water is taken from Muara Halayung Village at Banjar Region, South Kalimantan-Indonesia (3°29'57.7"S 114°34'20.9"E). Membrane support derived from α-alumina disc membrane with pore size 100 µm (Ceramics Oxide Fabricators, Australia). Silica pectin sols is generally fabricated from Tetraethyl Orthosilicate (TEOS, 99%, Sigma-

Aldrich), ethanol (96%), ammonia (0.00003N, Merck), nitric acid (0.0008N, Merck), pectin from banana peels (0.5%), and glycerol (85%, Merck).

2.2 Membrane Fabrication and Characterization

Silica pectin sols is synthesized by following our previous work [18,19]. TEOS mixed with Ethanol for 5 minutes 0 ºC. Then, HNO_3 is added into solution for an hour at 50 ºC. Afterwards, NH_3 is added by dropwise under stirring for 2 hours at the same condition. Next, check the solution pH of pure silica sols become 6. The pectin is dissolved into 5 ml glycerol and then stir well for 95 minutes at 50 ºC. Finally, 0.5 wt.% banana peels pectin template are added into sols and stir it still for 45 minutes at 0 ºC. Banana peels pectin template silica sol gel was dried for 24 h at 60 ºC and then grounded as xerogels for characterization. The homogenous xerogel powder are calcinated for 2 h at 300 ºC using Conventional thermal processing (CTP) technique. Then, the Fourier Transform Infra-Red (FTIR) spectra is carried out to measure the functional groups in silica pectin sol. For the last process, Alumina disk plate is coated with silica pectin sol by swab technique. Then, the coated membrane is calcinated for 2 hours at 300 ºC by CTP technique. Coating processes are done as much as 4 layers. The morphology and thickness of membrane are characterized by Scanning Electron Microscopy (SEM).

2.3 Membrane Ultrafiltration

The membrane is installed to the ultrafiltration set-up by dead-end method as shown in Figure 1. Wetland water as a feed was filled into reactor before ultrafiltration process runs and then close all valves except compressor valves. Next, ultrafiltration process run with various pressure (0.5 bar, 1 bar and 1.5 bar). The water flux ($kg.m^{-2}.h^{-1}$) and rejection are calculated using equations below.

$$F = \frac{m}{(A\Delta t)} \tag{1}$$

$$R = \frac{Cf - Cp}{Cf} \mathrm{X}100\% \tag{2}$$

m is flux mass (kg), A is the surface-active area of membrane (m^{-2}), Δt is operation time (hour), R is removal /rejection efficiency (F), Cf and Cp are the feed and permeate concentration and flux concentration. The NOM removal is measured by UV254 parameter (Spectrophotometer Genesys 10S UV-Vis). Salt rejection is estimated from calibration curve that suit with conductivity data measured (OHAUS ST300C).

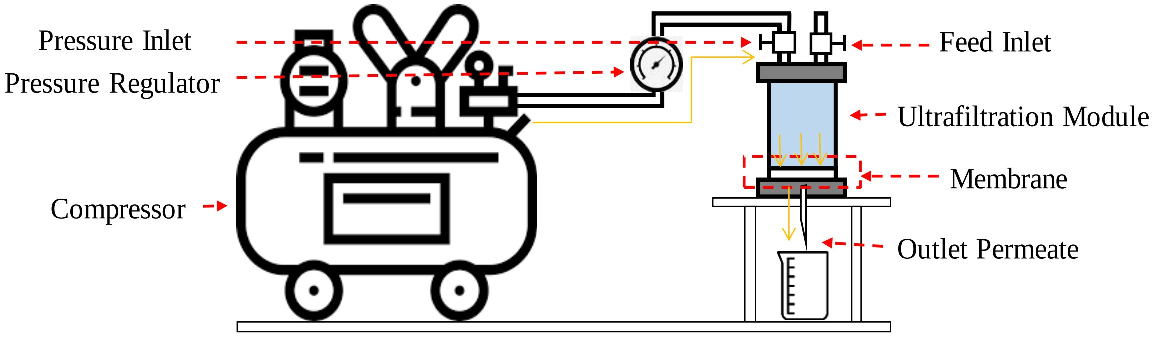

Fig. 1. Illustration of ultrafiltration experiment set up

3. Results

3.1 Membrane Characterization

3.1.1 Xerogel characterization

The FTIR spectra is carried out to measure the functional groups in silica pectin sol [7]. The FTIR spectra of silica pectin xerogel are shown in Figure 2. The result show xerogels has siloxane (Si-O-Si), silanol (Si-OH) and silica carbon (Si-C) functional groups. Siloxane functional groups are detected at wavelength 1061 cm^{-1}. Then at wavelength 966 cm^{-1} indicates the presence of silanol and the other peak in the figure is silica carbon which detected at wavelength 795 cm^{-1}. This results practically similar to our previous research reported by Mustalifah *et al.,* [18]. It explains siloxane at wavelength 1080 cm^{-1}, silanol at wavelength 976 cm^{-1} and silica carbon at wavelength 790 cm^{-1}. Siloxane functional groups is shaping membrane pores into mesopore. But more silanol effect the smaller form size (micropores). The combination between siloxane and silanol increase the membrane performance. These results are water flux becomes lower and transportation resistance gets higher. It means that a better rejection [4]. The presence of silica carbon groups is due to the addition banana peels pectin as carbon resource that increase strength and membrane hydro stability. Moreover, silica carbon support siloxane establishment [39].

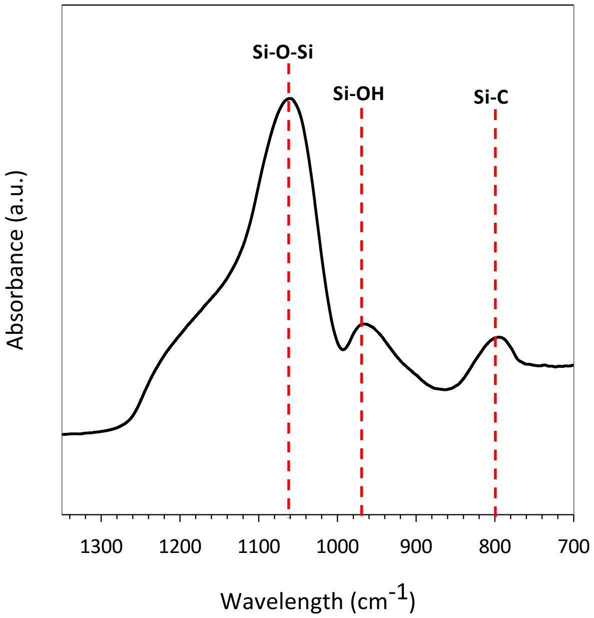

Fig. 2. FTIR spectra for the xerogel silica pectin

3.1.2 Membrane morphology

The structure of the silica-pectin membrane was analysed using Scanning Electron Microscopy (SEM) which shows on Figure 3. SEM analysis aims to determine the surface morphological structure of the membrane. The surface form of the membrane can affect the performance of membrane [14,18]. Figure 3 and Figure 4 show the SEM image of surface and cross-section silica pectin membrane by swab coating technique.

In Figure 3 silica pectin membrane in this work shows rough on the surface, where alumina particles look clearly. In fact, silica pectin sol infiltration into alumina membrane support similar to Elma *et al.,* [46] previous research. This is related to the dry porous surface contact and sol, which induces wetting forces like capillary forces and modulated by surface liquid tension [47]. Figure 4 show cross-section image of silica pectin membrane. Cross-section identify the formation of the coating layer attached [14]. Based on Figure 4 shows top part of the membrane does not show thin film formation. The silica pectin sol gets infiltrated into the pores of the alumina membrane support. It has been proved that the top part of the membrane is denser than the lower level in Figure 4. Swab technique in this work makes less silica pectin sol used than other coating methods and so silica pectin thin film membrane does not form. Refer to our previous work reported thin film sol can fill the pores of the membrane support which has big pores size (100 µm) [28].

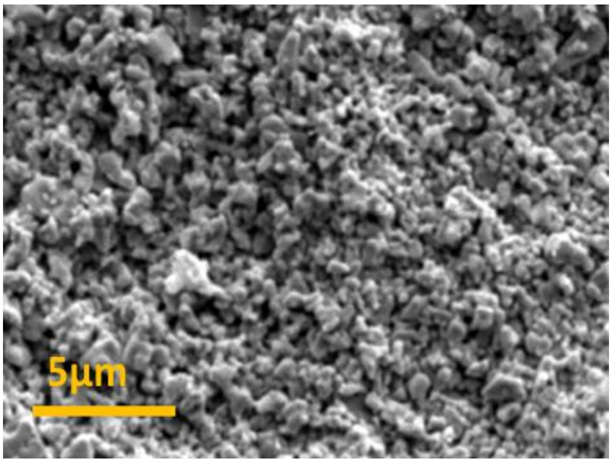

Fig. 3. SEM image of silica pectin membrane for top surface

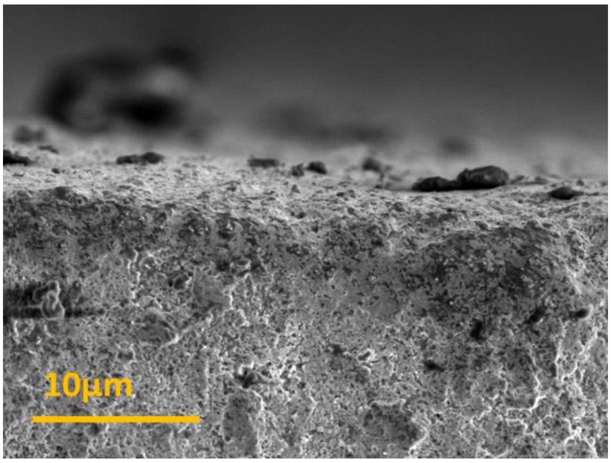

Fig. 4. SEM image of silica pectin membrane for cross-section

3.2 Characteristic of Wetland Water

The type of wetland water used is peat water and wetland saline water. Peat water is obtained from Suka maju village and wetland saline water are from Muara Halayung village, South Kalimantan-Indonesia. Generally, these wetland water have low qualities due to its characters. The characteristic of these water is writen in Table 1. pH value of these wetland water is below of the drinking water standard quality. These pH results are not much different than previous research by Rahma *et al.,* [48] and Elma *et al.,* [44] with the same type of water. UV 254 is representing aromatic NOM [26]. UV254 value in peat water and wetland saline water show high content of NOM. Same results are obtained from previous research by Rahma *et al.,* [48] which classify the wetland water has high UV254 value.

Table 1
Characteristics of wetland water

Parameters	Feeds		Unit	Standard
	Peat Water	Wetland Saline Water		
pH	5.14	6.35	-	6.5-8.5
UV_{254}	0.947	0.396	cm^{-1}	-
Conductivity	58.03	10500	$\mu S.cm^{-1}$	-

3.3 Membrane Performance

3.3.1 Membrane water flux

Banana peels pectin template silica ultrafiltration membrane performance is rated by water flux, UV254 and salt rejection in the various pressure operation. Higher flux and removal value signify high performance of silica pectin membrane in treating water [22]. This research conducted with 3 various ultrafiltration operating pressure (0.5 bar, 1 bar and 1.5 bar). Figure 5 shows the influence of pressure on the silica pectin membrane performance. Based on the result from 0.5- 1.5 bar, peat water flux obtains 5.07 – 18.90 $kg.m^{-2}.h^{-1}$. Besides, wetland saline water has preponderant water flux. They are 7.04 – 20.52 $kg.m^{-2}.h^{-1}$. This result exhibits higher pressure obtains higher water flux [26,49]. Similar result is obtained from other research by Elma *et al.,* [50] that higher filtration pressure affects membrane operation driving force so the water flux enhanced. Also, the graph define wet saline water flux are higher than peat water. This different result of water flux ultrafiltration is caused by particulate concentration contained in water. Water fluxes are decreasing along increasing NOM concentration which represented by UV254. NOM particulate are attached in the pores and affect the permeability [51]. Shown in Table 1 that peat water UV254 value is higher than wetland saline water thus proving lower water flux.

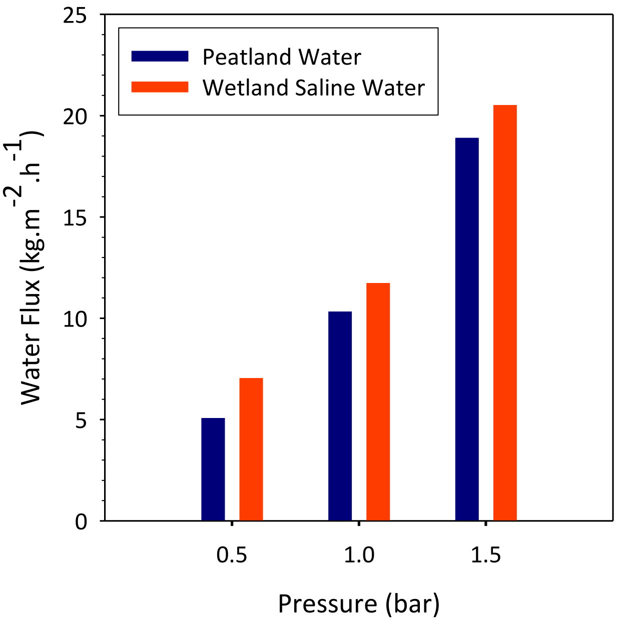

Fig. 5. Water flux performance of wetland water ultrafiltration on silica pectin membrane

3.3.2 NOM removal

Figure 6 shows the NOM removal efficiency ultrafiltration performance. NOM removal are determined by UV254, indicating aromatics/hydrophobics compounds can be preferentially removed over membrane [26,52]. Peat water removal obtain 85.56, 85.49 and 84.68 wt.% and wetland saline water is 82.50, 79.46 and 78.11 wt.% sequentially by pressure. Generally, the removal efficiency of NOM decreased along increasing pressure. The result is obtained by previous studies that the magnitude of NOM removal is inversely proportional to the applied pressure [50]. The deformation of the membrane due to high pressure, which causes membrane compaction that constrict the pore size and thicker foulant layer that became the secondary filter on top of the silica-pectin membrane. These results demonstrated that no remarkable differences when varying pressure and feeds which differences NOM concentration values. It is just NOM removal efficiency of peat water are higher than wetland saline water. The differences NOM removal efficiency are due to NOM concentration feed [52]. Increasing NOM will increase NOM removal efficiency. During ultrafiltration runs, NOM particulate are deposited on the membrane surface and pores so increase removal efficiency and decrease water flux [53].

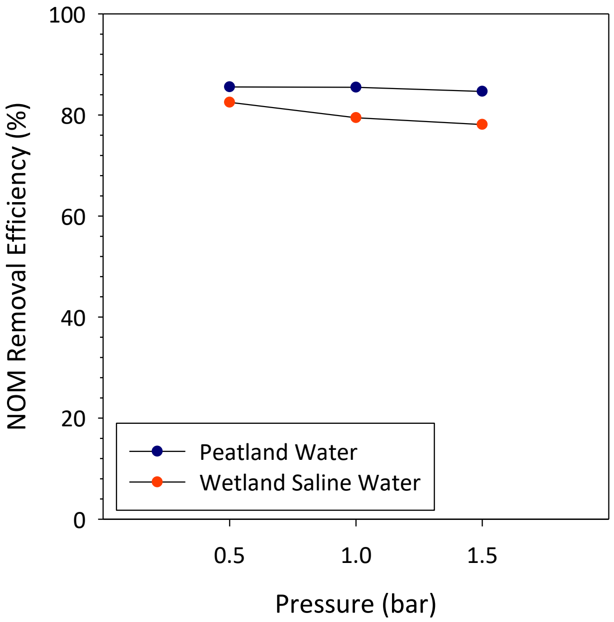

Fig. 6. NOM removal efficiency represented by UV 254 absorbances

3.3.3 Salt rejection

Salt rejection shows the ratio of the amount of salt concentration into the feed towards water permeate [41]. Salt concentration are corelated to conductivities of the water determined by a conductivity metre [42]. This experiment pointing on wetland saline water because it is classified as sea water typical with higher salt concentration (1-3.5%) [54].

Figure 7 shows the influence of pressure on salt rejection for silica pectin membrane ultrafiltration. Experimental runs have allowed to detect a decreasing salt rejection as a function of pressure operation on silica pectin membrane. Results showed decreasing salt rejection from 84.39% to 81.04% along increasing pressure. This is due to the increase in flux with increasing operating pressure which enhances the degree of concentration polarization and thus reduces the salt rejection due to higher concentration of salt in the solution deposited onto the membrane and undermines the contribution of diffusion relative to convective salt transport [1,55]. Besides, salt rejection occurs by silica-pectin coated on membrane which is in the diameter range between water molecule and hydrated salt ions [56].

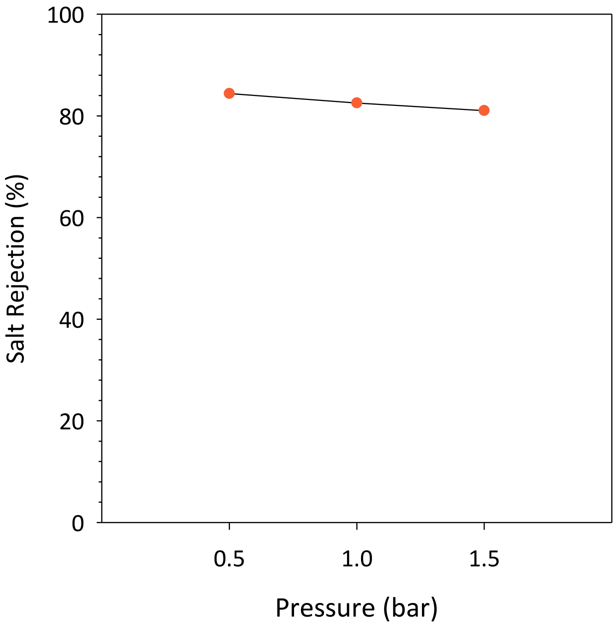

Fig. 7. Salt rejection performance

4. Conclusions

This work silica-pectin membrane has been successfully fabricated silica pectin membrane by CTP calcination process. The FTIR spectra of silica pectin membrane indicates siloxane (Si-O-Si), silanol (Si-OH) and silica carbon (Si-C) functional groups. Ultrafiltration performance on various pressure show water flux reach 18.90 kg.m^{-2}.h^{-1} on peat water and 20.52 kg.m^{-2}.h^{-1} on wetland saline water in 1.5 bar pressure operation. The highest value of NOM removal efficiency in peatland water reaches 85.56% and wetland saline water is 82.50% in 0.5 bar. Be sides, salt rejection ability in wetland saline water shows 84.39% rejection in 0.5 bar and decreasing along increasing pressure operation. These results define increasing water flux by increasing pressure operation affected decreasing NOM removal efficiency and salt rejection.

Acknowledgement

All authors acknowlegde Materials and Membranes Research Group (M^{2}ReG) for the facilities. Muthia Elma also thanks to Applied Research Universities Grant 2021-2023, Thesis and Dissertation Grant 2022 the Ministry of Research and Technology/National Research and Innovation Agency, The Ministry of Education and Culture of the Republic of Indonesia. Rhafiq AG also thanks to Indofood Riset Nugraha (IRN) Grant supported by PT Indofood Sukses Makmur Merdeka Tbk. Aulia Rahma gratitudes to Kurita Asia Research Grant 2021 (KARG)-Grant No. 21Pid028-10 I.

References

[1] Elma, Muthia, Christelle Yacou, João C. Diniz da Costa, and David K. Wang. "Performance and long term stability of mesoporous silica membranes for desalination." *Membranes* 3, no. 3 (2013): 136-150. https://doi.org/10.3390/membranes3030136

[2] Isa, Eleen Dayana Mohamed, Kamyar Shameli, Roshafima Rasheid Ali, and Vekes Balasundram. "Advances in Nanocellulose Based Materials as Adsorbent for Wastewater Treatment." *Journal of Research in Nanoscience and Nanotechnology* 5, no. 1 (2022): 43-64. https://doi.org/10.37934/jrnn.5.1.4364

[3] Hubadillah, Siti Khadijah, Zhong Sheng Tai, Mohd Hafiz Dzarfan Othman, Zawati Harun, Mohd Riduan Jamalludin, Mukhlis A. Rahman, Juhana Jaafar, and Ahmad Fauzi Ismail. "Hydrophobic ceramic membrane for membrane distillation: A mini review on preparation, characterization, and applications." *Separation and Purification Technology* 217 (2019): 71-84. https://doi.org/10.1016/j.seppur.2019.02.014

[4] Elma, Muthia, and Nur Riskawati. "Silica membranes for wetland saline water desalination: performance and long term stability." In *IOP Conference Series: Earth and Environmental Science*, vol. 175, no. 1, p. 012006. IOP Publishing, 2018. https://doi.org/10.1088/1755-1315/175/1/012006

[5] Heston, Yudha P., and Nur Alvira Pascawati. "Problem and technology solution improving water quality in Morotai Island (A case study in Koloray, Muhajirin and Juanga)." *Technology in Society* 65 (2021): 101552. https://doi.org/10.1016/j.techsoc.2021.101552

[6] Chair, Miftahul, Fadly H. Yusran, Husaini Husaini, and Nasruddin Nasruddin. "Distribution Of Slums, Building Configuration, And Land Cover Composition in Banjarmasin City, South Kalimantan Province, Indonesia Using a Geographic Information System." *Review of International Geographical Education* 11, no. 5 (2021): 2979-2990.

[7] Lestari, Riani Ayu, Muthia Elma, Aulia Rahma, Dewi Suparsih, Syarifah Anadhliyah, Norlian Ledyana Sari, Dhimas Ari Pratomo et al. "Organo silica membranes for wetland saline water desalination: effect of membranes calcination temperatures." In *E3S Web of Conferences*, vol. 148, p. 07006. EDP Sciences, 2020. https://doi.org/10.1051/e3sconf/202014807006

[8] Wenten, I. G., K. Khoiruddin, A. K. Wardani, P. T. P. Aryanti, D. I. Astuti, and A. A. I. A. S. Komaladewi. "Preparation of antifouling polypropylene/ZnO composite hollow fiber membrane by dip-coating method for peat water treatment." *Journal of Water Process Engineering* 34 (2020): 101158. https://doi.org/10.1016/j.jwpe.2020.101158

[9] Elma, Muthia, Aulia Rahma, Amalia E. Pratiwi, and Erdina L. A. Rampun. "Coagulation as pretreatment for membrane-based wetland saline water desalination." *Asia-Pacific Journal of Chemical Engineering* 15, no. 4 (2020): e2461. https://doi.org/10.1002/apj.2461

[10] Rahma, Aulia, Muthia Elma, Erdina LA Rampun, Sintong Leonardo Sintungkir, and Muhammad Farid Hidayat. "Effect of backwashing process on the performance of an interlayer-free silica-pectin membrane applied to wetland saline water pervaporation." *Membrane Technology* 2022, no. 2 (2022). https://doi.org/10.12968/S0958-2118(22)70019-5

[11] Mat Nawi, Normi Izati, Afiq Mohd Lazis, Aulia Rahma, Muthia Elma, Muhammad Roil Bilad, Nik Abdul Hadi Md Nordin, Mohd Dzul Hakim Wirzal, Norazanita Shamsuddin, Hazwani Suhaimi, and Norhaniza Yusof. "A Rotary Spacer System for Energy-Efficient Membrane Fouling Control in Oil/Water Emulsion Filtration." *Membranes* 12, no. 6 (2022): 554. https://doi.org/10.3390/membranes12060554

[12] Elma, Muthia, Amalia Enggar Pratiwi, Aulia Rahma, Erdina Lulu Atika Rampun, Mahmud Mahmud, Chairul Abdi, Raissa Rosadi, Dede Heri Yuli Yanto, and Muhammad Roil Bilad. "Combination of coagulation, adsorption, and ultrafiltration processes for organic matter removal from peat water." *Sustainability* 14, no. 1 (2021): 370. https://doi.org/10.3390/su14010370

[13] Elma, Muthia, Eggy A. Pradana, Muhammad D. Ul-haq, Erdina LA Rampun, Aulia Rahma, Awali SK Harivram, Zaini L. Assyaifi, and Yayan Kamelia. "Hollow fiber membrane applied for Sasirangan wastewater desalination integrated with photocatalysis and pervaporation set-up." *Materials Today: Proceedings* 51 (2022): 1298-1302. https://doi.org/10.1016/j.matpr.2021.10.343

[14] Elma, Muthia, Muhammad Roil Bilad, Amalia Enggar Pratiwi, Aulia Rahma, Zaini Lambri Asyyaifi, Hairullah Hairullah, Isna Syauqiah, Yulian Firmana Arifin, and Riani Ayu Lestari. "Long-Term Performance and Stability of Interlayer-Free Mesoporous Silica Membranes for Wetland Saline Water Pervaporation." *Polymers* 14, no. 5 (2022): 895. https://doi.org/10.3390/polym14050895

[15] Waqas, Sharjeel, Muhammad Roil Bilad, Zakaria B. Man, Humbul Suleman, Nik Abdul Hadi Nordin, Juhana Jaafar, Mohd Hafiz Dzarfan Othman, and Muthia Elma. "An energy-efficient membrane rotating biological contactor for wastewater treatment." *Journal of Cleaner Production* 282 (2021): 124544. https://doi.org/10.1016/j.jclepro.2020.124544

[16] Sumardi, Anna, Muthia Elma, Erdina Lulu Atika Rampun, Aptar Eka Lestari, Zaini Lambri Assyaifi, Adi Darmawan, Dede Heri Yuli Yanto, Isna Syauqiah, Yanti Mawaddah, and Linda Suci Wati. "Designing a mesoporous hybrid

organo-silica thin film prepared from an organic catalyst." *Membrane Technology* 2021, no. 2 (2021): 5-8. https://doi.org/10.1016/S0958-2118(21)00029-X

[17] Pradhana, E. A., M. Elma, M. H. D. Othman, N. Huda, M. D. Ul-Haq, Erdina L. A. Rampun, and A. Rahma. "The functionalization study of PVDF/TiO_2 hollow fibre membranes under vacuum calcination exposure." In *Journal of Physics: Conference Series*, vol. 1912, no. 1, p. 012035. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1912/1/012035

[18] Mustalifah, F. R., A. Rahma, and M. Elma. "Chemical cleaning to evaluate the performance of silica-pectin membrane on acid mine drainage desalination." In *IOP Conference Series: Materials Science and Engineering*, vol. 1195, no. 1, p. 012057. IOP Publishing, 2021. https://doi.org/10.1088/1757-899X/1195/1/012057

[19] Elma, Muthia, Anna Sumardi, Adhe Paramita, Aulia Rahma, Aptar Eka Lestari, Dede Heri Yuli Yanto, Sutarto Hadi, Zaini Lambri Assyaifi, and Yanuardi Raharjo. "Physicochemical properties of mesoporous organo-silica xerogels fabricated through organo catalyst." *Membranes* 11, no. 8 (2021): 607. https://doi.org/10.3390/membranes11080607

[20] Syauqiah, I., M. Elma, D. P. Mailani, and N. Pratiwi. "Activated carbon from Nypa (Nypa fruticans) leaves applied for the Fe and Mn removal." In *IOP Conference Series: Materials Science and Engineering*, vol. 980, no. 1, p. 012073. IOP Publishing, 2020. https://doi.org/10.1088/1757-899X/980/1/012073

[21] Rahman, Sazila Karina, Aulia Rahma, Isna Syauqiah, and Muthia Elma. "Functionalization of hybrid organosilica based membranes for water desalination-Preparation using Ethyl Silicate 40 and P123." *Materials Today: Proceedings* 31 (2020): 60-64. https://doi.org/10.1016/j.matpr.2020.01.187

[22] Rahma, Aulia, Muthia Elma, Erdina Lulu Atika Rampun, Amalia Enggar Pratiwi, Arief Rakhman, and Fitriani Fitriani. "Rapid thermal processing and long term stability of interlayer-free silica-P123 membranes for wetland saline water desalination." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 71, no. 2 (2020): 1-9. https://doi.org/10.37934/arfmts.71.2.19

[23] Rahma, Aulia, Muthia Elma, Amalia E. Pratiwi, and Erdina L. A. Rampun. "Performance of interlayer-free pectin template silica membranes for brackish water desalination." *Membrane Technology* 2020, no. 6 (2020): 7-11. https://doi.org/10.1016/S0958-2118(20)30108-7

[24] Nabilah, N. N. Ain, Ratri Rahmawati, M. R. Bilad, A. E. Pratiwi, Muthia Elma, and Norwahyu Jusoh. "Finned spacer panel system for fouling control in Chlorella vulgaris harvesting." In *IOP Conference Series: Materials Science and Engineering*, vol. 736, no. 6, p. 062009. IOP Publishing, 2020. https://doi.org/10.1088/1757-899X/736/6/062009

[25] Maimunawaro, Maimunawaro, Sazila Karina Rahman, Erdina Lulu Atika Rampun, Aulia Rahma, and Muthia Elma. "Deconvolution of carbon silica templated thin film using ES40 and P123 via rapid thermal processing method." *Materials Today: Proceedings* 31 (2020): 75-78. https://doi.org/10.1016/j.matpr.2020.01.195

[26] Mahmud, Mahmud, Muthia Elma, Erdina Lulu Atika Rampun, Aulia Rahma, Amalia Enggar Pratiwi, Chairul Abdi, and Raisa Rossadi. "Effect of two stages adsorption as pre-treatment of natural organic matter removal in ultrafiltration process for peat water treatment." In *Materials Science Forum*, vol. 988, pp. 114-121. Trans Tech Publications Ltd, 2020. https://doi.org/10.4028/www.scientific.net/MSF.988.114

[27] Elma, Muthia, N. L. Sari, D. A. Pratomo, S. Annadliyah, E. L. A. Rampun, A. Rahma, and A. E. Pratiwi. "Organo-silica membrane for brine water pervaporation." In *IOP Conference Series: Earth and Environmental Science*, vol. 473, no. 1, p. 012129. IOP Publishing, 2020. https://doi.org/10.1088/1755-1315/473/1/012129

[28] Elma, Muthia, and Gesit Satriaji Saputro. "Performance of cobalt-silica membranes through pervaporation process with different feed solution concentrations." In *Materials Science Forum*, vol. 981, pp. 342-348. Trans Tech Publications Ltd, 2020. https://doi.org/10.4028/www.scientific.net/MSF.981.342

[29] Meng, Shujuan, Minmin Zhang, Meng Yao, Zhuguo Qiu, Yubin Hong, Weiguang Lan, Haiping Xia, and Xue Jin. "Membrane fouling and performance of flat ceramic membranes in the application of drinking water purification." *Water* 11, no. 12 (2019): 2606. https://doi.org/10.3390/w11122606

[30] Othman, Mohd Hafiz Dzarfan, Mohd Ridhwan Adam, Mohammad Arif Budiman Pauzan, Siti Khadijah Hubadillah, Mukhlis A. Rahman, and Juhana Jaafar. "Ultrafiltration Membrane for Water Treatment." In *Self-standing Substrates*, pp. 119-145. Springer, Cham, 2020. https://doi.org/10.1007/978-3-030-29522-6_4

[31] Moslehyani, Ali, Ahmad Fauzi Ismail, Takeshi Matsuura, Mukhlis A. Rahman, and Pei Sean Goh. "Recent progresses of ultrafiltration (UF) membranes and processes in water treatment." In *Membrane Separation Principles and Applications*, pp. 85-110. Elsevier, 2019. https://doi.org/10.1016/B978-0-12-812815-2.00003-X

[32] Lestari, Riani Ayu, Muthia Elma, Erdina Lulu Atika Rampun, Anna Sumardi, Adhe Paramitha, Aptar Eka Lestari, Sadidan Rabiah, Zaini Lambri Assyaifi, and Gesit Satriaji. "Functionalization of Si-C using TEOS (tetra ethyl ortho silica) as precursor and organic catalyst." In *E3S Web of Conferences*, vol. 148, p. 07008. EDP Sciences, 2020. https://doi.org/10.1051/e3sconf/202014807008

[33] Elma, Muthia, Erdina LA Rampun, Aulia Rahma, Zaini L. Assyaifi, Anna Sumardi, Aptar E. Lestari, Gesit S. Saputro, Muhammad Roil Bilad, and Adi Darmawan. "Carbon templated strategies of mesoporous silica applied for water

desalination: A review." *Journal of Water Process Engineering* 38 (2020): 101520. https://doi.org/10.1016/j.jwpe.2020.101520

[34] Elma, Muthia, Amalia Enggar Pratiwi, Aulia Rahma, Erdina Lulu Atika Rampun, and Noni Handayani. "The performance of membranes interlayer-free silica-pectin templated for seawater desalination via pervaporation operated at high temperature of feed solution." In *Materials Science Forum*, vol. 981, pp. 349-355. Trans Tech Publications Ltd, 2020. https://doi.org/10.4028/www.scientific.net/MSF.981.349

[35] Elma, Muthia, Dwi Rasy Mujiyanti, Noor Maizura Ismail, Muhammad Roil Bilad, Aulia Rahma, Sazila Karina Rahman, Fitriani Fitriani, Arief Rakhman, and Erdina Lulu Atika Rampun. "Development of hybrid and templated silica-P123 membranes for brackish water desalination." *Polymers* 12, no. 11 (2020): 2644. https://doi.org/10.3390/polym12112644

[36] Pratiwi, Amalia Enggar, Muthia Elma, Aulia Rahma, Erdina L. A. Rampun, and Gesit Satriaji Saputro. "Deconvolution of pectin carbonised template silica thin-film: synthesis and characterisation." *Membrane Technology* 2019, no. 9 (2019): 5-8. https://doi.org/10.1016/S0958-2118(19)30167-3

[37] Elma, Muthia, Heru Setyawan, Aulia Rahma, A. E. Pratiwi, and Erdina Lulu A. Rampun. "Fabrication of Interlayer-free P123 Caronised Template Silica Membranes for Water Desalination: Conventional Versus Rapid Thermal Processing (CTP vs RTP) Techniques." In *IOP Conference Series: Materials Science and Engineering*, vol. 543, no. 1, p. 012076. IOP Publishing, 2019. https://doi.org/10.1088/1757-899X/543/1/012076

[38] Elma, Muthia, Riani Ayu, Erdina LA Rampun, Syarifah Annahdliyah, Dewi R. Suparsih, Norlian Ledyana Sari, and Dhimas Ari Pratomo. "Fabrication of interlayer-free silica-based membranes-effect of low calcination temperature using an organo-catalyst." *Membrane Technology* 2019, no. 2 (2019): 6-10. https://doi.org/10.1016/S0958-2118(19)30037-0

[39] Elma, Muthia, and Heru Setyawan. "Synthesis of silica xerogels obtained in organic catalyst via sol gel route." In *IOP Conference Series: Earth and Environmental Science*, vol. 175, no. 1, p. 012008. IOP Publishing, 2018. https://doi.org/10.1088/1755-1315/175/1/012008

[40] Elma, Muthia, and Nur Riskawati. "Silica membranes for wetland saline water desalination: performance and long term stability." In *IOP Conference Series: Earth and Environmental Science*, vol. 175, no. 1, p. 012006. IOP Publishing, 2018. https://doi.org/10.1088/1755-1315/175/1/012006

[41] Elma, Muthia, and Zaini Lambri Assyaifi. "Desalination process via pervaporation of wetland saline water." In *IOP Conference Series: Earth and Environmental Science*, vol. 175, no. 1, p. 012009. IOP Publishing, 2018. https://doi.org/10.1088/1755-1315/175/1/012009

[42] Elma, Muthia, Arief Rakhman, and Rahmi Hidayati. "Silica P123 Membranes for desalination of wetland saline water in South Kalimantan." In *IOP Conference Series: Earth and Environmental Science*, vol. 175, no. 1, p. 012007. IOP Publishing, 2018. https://doi.org/10.1088/1755-1315/175/1/012007

[43] Elma, Muthia, Erdina LA Rampun, Aulia Rahma, Zaini L. Assyaifi, Anna Sumardi, Aptar E. Lestari, Gesit S. Saputro, Muhammad Roil Bilad, and Adi Darmawan. "Carbon templated strategies of mesoporous silica applied for water desalination: A review." *Journal of Water Process Engineering* 38 (2020): 101520. https://doi.org/10.1016/j.jwpe.2020.101520

[44] Elma, Muthia, Fitri Ria Mustalifah, Lilis Suryani, Erdina Lulu Atika Rampun, and Aulia Rahma. "Wetland saline water and acid mine drainage desalination by interlayefree silica pectin membrane from banan peels." *Nusantara Science and Technology Proceedings* (2020): 271-279.

[45] Syauqiyah, Isna, Muthia Elma, Meilana D. Putra, Aulia Rahma, Amalia E. Pratiwi, and Erdina L. A. Rampun. "Interlayer-free silica-carbon template membranes from pectin and P123 for water desalination." In *MATEC Web of Conferences*, vol. 280, p. 03017. EDP Sciences, 2019. https://doi.org/10.1051/matecconf/201928003017

[46] Elma, Muthia, David K. Wang, Christelle Yacou, and João C. Diniz da Costa. "Interlayer-free P123 carbonised template silica membranes for desalination with reduced salt concentration polarisation." *Journal of Membrane Science* 475 (2015): 376-383. https://doi.org/10.1016/j.memsci.2014.10.026

[47] Yang, Hong, Muthia Elma, David K. Wang, Julius Motuzas, and João C. Diniz da Costa. "Interlayer-free hybrid carbon-silica membranes for processing brackish to brine salt solutions by pervaporation." *Journal of Membrane Science* 523 (2017): 197-204. https://doi.org/10.1016/j.memsci.2016.09.061

[48] Rahma, Aulia, Muthia Elma, Mahmud Mahmud, Chairul Irawan, Amalia Enggar Pratiwi, and Erdina Lulu Atika Rampun. "Removal of natural organic matter for wetland saline water desalination by coagulation-pervaporation." *Jurnal Kimia Sains dan Aplikasi* 22, no. 3 (2019): 85-92. https://doi.org/10.14710/jksa.22.3.85-92

[49] He, Zeming, Tze Chiang Albert Ng, Zhiyang Lyu, Qilin Gu, Lei Zhang, How Yong Ng, and John Wang. "Alumina double-layered ultrafiltration membranes with enhanced water flux." *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 587 (2020): 124324. https://doi.org/10.1016/j.colsurfa.2019.124324

[50] Elma, Muthia, Amalia Enggar Pratiwi, Aulia Rahma, Erdina Lulu Atika Rampun, Mahmud Mahmud, Chairul Abdi, Raissa Rosadi, Dede Heri Yuli Yanto, and Muhammad Roil Bilad. "Combination of coagulation, adsorption, and

ultrafiltration processes for organic matter removal from peat water." *Sustainability* 14, no. 1 (2021): 370. https://doi.org/10.3390/su14010370

[51] Prisciandaro, Marina, and Giuseppe Mazziotti di Celso. "On the removal of natural organic matter from superficial water by using UF and MF membranes." *Desalination and Water Treatment* 57, no. 6 (2016): 2481-2488. https://doi.org/10.1080/19443994.2015.1031184

[52] Xia, Shengji, Yumin Zhou, Rui Ma, Yijun Xie, and Jianwei Chen. "Ultrafiltration of humic acid and surface water with tubular ceramic membrane." *Desalination and Water Treatment* 51, no. 25-27 (2013): 5319-5326. https://doi.org/10.1080/19443994.2013.768791

[53] Metsämuuronen, Sari, Mika Sillanpää, Amit Bhatnagar, and Mika Mänttäri. "Natural organic matter removal from drinking water by membrane technology." *Separation & Purification Reviews* 43, no. 1 (2014): 1-61. https://doi.org/10.1080/15422119.2012.712080

[54] Elma, Muthia, Christelle Yacou, David K. Wang, Simon Smart, and João C. Diniz da Costa. "Microporous silica based membranes for desalination." *Water* 4, no. 3 (2012): 629-649. https://doi.org/10.3390/w4030629

[55] Lin, Jiuyang, Wenyuan Ye, Marian-Cornel Baltaru, Yu Pan Tang, Nicole J. Bernstein, Peng Gao, Stefan Balta et al. "Tight ultrafiltration membranes for enhanced separation of dyes and Na_2SO_4 during textile wastewater treatment." *Journal of Membrane Science* 514 (2016): 217-228. https://doi.org/10.1016/j.memsci.2016.04.057

[56] He, Zeming, Zhiyang Lyu, Qilin Gu, Lei Zhang, and John Wang. "Ceramic-based membranes for water and wastewater treatment." *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 578 (2019): 123513. https://doi.org/10.1016/j.colsurfa.2019.05.074