Hollow fiber membrane applied for Sasirangan wastewater desalination integrated with photocatalysis and pervaporation set-up

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Hollow fiber membrane applied for *Sasirangan* wastewater desalination integrated with photocatalysis and pervaporation set-up

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ABSTRACT

Nowadays, the difficulty to access a clean water has been increased due to environmental pollution by human activities. Sasirangan is a traditional fabric from South Kalimantan. The process produced a wastewater which contains a high concentration of textile dye and total dissolved solids (TDS). It is carcinogenic to humans and potentially dangerous to biota. To overcome this problem, a hollow fiber membrane technology has employed to reject the contaminants from Sasirangan wastewater. The purpose of this study to determinate the performance of pervaporation hollow fiber membrane-photocatalytic for treating the Sasirangan wastewater. TiO_2 has chosen as a catalyst in photocatalytic process with variations of 0; 0.5; 1; 1.5; 2; and 2.5%. These processes provide the highest water flux of 4.35 Kg.m^{-2}.h^{-1} as well as good rejection in color of 98.02%, TDS of 2.345 mg/L, and conductivity (3.5µS) for 2.5% TiO_2. Overall, the photocatalytic coupling with the pervaporation resulting in a remarkable effect on pollutants rejection for Sasirangan wastewater.

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1. Introduction

Sasirangan wastewater is the contributor of environmental pollution in South Kalimantan. It is a by-product from a textile home industry which is known as the cultural fabric of the Banjar tribe. Generally, the Sasirangan wastewater is derived by a dyeing process and a residue of washing process. It was commonly disposed into the environment. The untreated Sasirangan wastewater contains the metal complex dyes (Pb, Cu, Cd, etc)[1] which are harmful to living things and environment. The Sasirangan wastewater has a colour concentration of 3200 PtCo/L[2]. Hence, it is necessary to choose a technology that can reduce the colour content of Sasirangan wastewater.

Nowadays, a photocatalytic has been gained interest because of the new approach technology for environmental contamination. A photocatalyst employed in this process has the ability to absorb photons. A photon energy absorbed may activate the catalytic process and releases hydroxyl radicals. It allows the color degradation. The most common catalyst utilized is Titanium dioxide (TiO_2) due to its abundance, effective, stable against photo corrosion, non-toxic to the humans and environment[3]. The TiO_2 is an inorganic hydrophilic material that also has an anti-fouling properties and high capacity of increasing a water permeability [4]. However, the photocatalytic process requires the catalyst [5]. Therefore, to reduce the use of TiO_2 catalyst, the coupling of photocatalytic and a membrane could be a promising technology.

Membrane pervaporation has several advantages such as less chemical, energy and no environmental impacts as well. Silica based membrane [6,7], organosilica [8–11], Silica-pectin [12–17], silica-P123 [18–20], cobalt-silica membrane [21] and hollow fiber TiO_2 membrane have been introduced to the water treatment technology [22,23]. Among all type, the hollow fiber membranes have high packing density, good mechanical support and ease of handling during the operation process. These distinguishing features make the membrane suit to be combined with photocatalytic. It would increase the lifetime of membrane and less catalyst addition.

The remarkable ability of membrane for textile wastewater treatment has reported for reduce color parameter. The research

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done by Cao et al and Gue et al [24,25] stated the membrane could reject the color up to 95%. However, the membrane fouling phenomenon might be a major concern here. The fouling phenomenon may cause the particles accumulation in membrane pores [26]. As a result, the flux reduction occurred. Hence, in this work, the combination of membrane and photocatalytic (hybrid process) was performed to reduce the membrane fouling. It utilizes the TiO_2 catalyst (0–2.5%) to treat the Sasirangan wastewater into clean water. Then, investigating the performance of the hollow fiber membrane-photocatalytic. This combination would reduce the color, TDS, and conductivity as well.

2. Methods

2.1. Materials and chemicals

Sasirangan wastewater as feed was collected from Cempaka Baru Sasirangan, Banjarbaru South Kalimantan-Indonesia. The materials and chemicals used in this work is titanium(IV) oxide (TiO_2) for analysis Merck, The PVDF-TiO_2 hollow fiber membrane materials and fabrication procedure is described detail in our previous work [23], a 18 W Philips UV-C lamp, liquid nitrogen Samator gas Industry- Indonesia, and demineralized water.

2.2. Pervaporation and photocatalytic wastewater of Sasirangan using PVDF-TiO_2 hollow fiber membrane

TDS, conductivity and color absorbance in Sasirangan wastewater were tested before and after treatment. This research was conducted by combining the pervaporation and photocatalytic processes. In the reactor, there are 4 UV lamps and test tube like shown on Fig. 1. The Sasirangan wastewater was put in the test tube. Then, the hollow fiber membrane was immersed into the Sasirangan wastewater. TiO_2 catalyst concentrations of 0, 0.5, 1, 1.5 and 2.5% were added into the Sasirangan wastewater. Then, the Sasirangan wastewater was irradiated by the UV light for 1 h.

A vacuum pressure was connected to the hollow fiber membrane to flow the permeate into a cold trap. The cold trap was soaked in the container filled with liquid nitrogen. Next, the water fluxes and color rejections were measured. Then, the TDS tested by TDS meter (OHAUS Starter 300C), conductivity measured by conductivity meter Lutron CD-4301, and color absorbance was tested by UV–Vis (UV-1600 Spectrophotometer) at 380 nm wavelength.

3. Results and discussions

Table 1 was summarized the Sasirangan wastewater characteristic before treatment. According to the table, it can be seen that the TDS (Total dissolve solid) and conductivity parameters are still meet the water standard of South Kalimantan Governor Regulation Number 36/2008 [19], but other parameter like percentage of hazardous component that was indicated by turbidity of wastewater [27] still not fit on textile wastewater standard. The TDS is a value that measure amount of substance that can be dissolved in the solution. While, cconductivity is the ability to conduct electricity in solution. The wastewater that discharged into the environment must be colourless and odorless [28]. This result of turbidity parameter value has similar with Nasrudin et al [29], of 74.7 NTU that means Sasirangan wastewater does not meet the water standard of South Kalimantan Governor Regulation Number 36/2008 as well. It indicated by high turbidity value.

Table 1
Characteristic of Sasirangan wastewater.

Parameter	Sample value	Quality standardSouth Kalimantan Governor Regulation No.36/2008	Unit
Color (UV_{380} nm)	0.76	–	cm^{-1}
Turbidity	74.7	1–5	NTU
TDS (total dissolve solid)	118.27	≤ 2000	mg/L
Conductivity	176.53	400	μS

As shown on Table 1 the TDS and conductivity parameters display still meet the quality standard according to South Kalimantan Governor Regulation Number 36/2008 for textile wastewater standard. The TDS parameter is under 2000 mg/L and conductivity is below to 400 μS. Based on the local regulation standard, the colour parameter has limit standard of 200Pt-Co. In this study, colour parameters were measured using UV/Vis spectrophotometer at wavelength 380 nm and shows value of 0.76 cm^{-1} absorbance. The absorbance spectrum for colour shows at 380–463 nm wavelength. In Maljaei, Arami and Mahmoodi [30] work obtains colour peak at 392 nm with absorbance value of 0.56 nm that indicated the intermediates and aromatic rings which contributed to colouring textile wastewater.

Fig. 2 presents that the best water flux of hollow fiber membranes-photocatalytic was 4.3516 kg $m^{-2}h^{-1}$ at 2.5% TiO_2 catalyst. Furthermore, the colour rejection was increased along with the TiO_2 concentration rises. The enhancing of TiO_2 concentration on photocatalysis has been affected to increasing of parameters rejection (colour). As the adding of TiO_2 concentration from 0.5 to 2.5 % TiO_2, the colour rejection also increases (Fig. 2). However, this result is contradicted to Khoiriah, Wellia and Safni [3] work, which states as loading of TiO_2 over the limit may lead degradation of photocatalytic to be obstructed due to catalyst agglomeration of the light disperse effect. In this case of study, the addition of TiO_2 concentration is only 0–2.5 %, that exhibits increasing performance

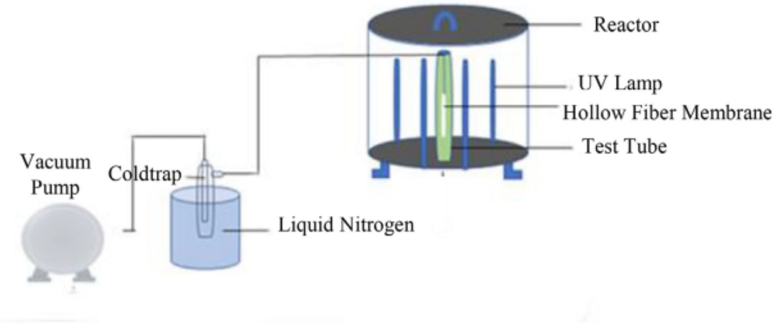

Fig. 1. Pervaporation-photocatalytic set-up.

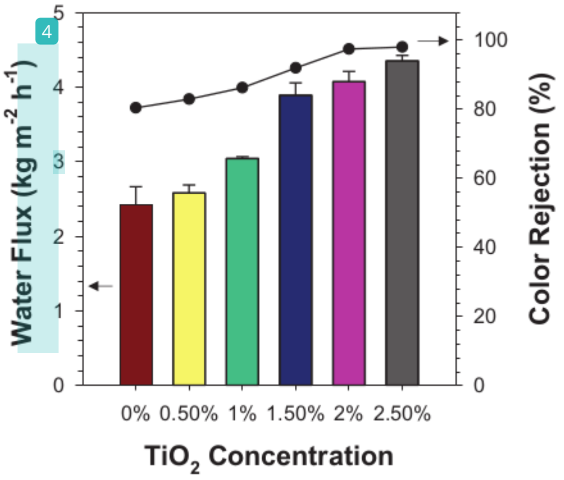

Fig. 2. Pervaporation–photocatalytic performance of hollow fiber membranes for Sasirangan wastewater based on water flux and colour rejection.

trend. Nevertheless, up to 2.5% the performance of photocatalytic-membrane might be decrease due to similar to the literature. The highest colour rejection was 98.02% for 2.5% TiO_2 and the lowest was 80.4% without catalyst. These results indicate that there is an improvement in pervaporation-photocatalytic performance for Sasirangan wastewater as the TiO_2 increased.

This result is comparable with Wang et al [31] research that employed the hollow fiber membrane with 3 concentrations variation of AO7 as feed. It has resulted the fluctuate permeate of pervaporation–photocatalytic process due to the membrane instability. Other studies were reported by Khoiriah et al [3] and Kajekar et al [32], which findings focus on colour rejection with TiO_2 addition. The TiO_2 has a dominant effect to reduce the percentage of dye/colour of textiles wastewater from 50,73% to 47%. In addition, the dye/colour reduction on textiles wastewater has found as the permeation pressures increased after passed it through the hollow fiber membrane in difference permeation pressures (2 bar and 4 bar). Although, when a membrane begins to undergo a fouling due to the high foulant concentration, there is a slightly reduction in catalyst reaction. Other study has also reported that the addition of TiO_2 to a membrane matrix enhanced the hydrophilicity material and selectivity [31]. Notodarmodjo et al [33] has stated that TiO_2 photocatalyst might be contribute to the membrane fouling which is known as foulant polarization. It causes blockages in the membrane pores and cake formation on the membrane surface as the higher TiO_2 concentration added. Then, there would be a decrease in the permeate flow.

Fig. 3 demonstrates the TDS rejection in Sasirangan wastewater after the TiO_2 was applied. The highest TDS was 98.86 mg/L at 0% and the lowest was 2,345 mg/L at 2.5% catalyst. Overall, this result proves that this process worthy to treat the Sasirangan wastewater to fulfil the textile wastewater standard [15]. The TDS could be removed by coupling the photocatalytic process and membrane pervaporation. Generally, the membrane selectivity depends on the membrane matrix. Not only the membrane that affects the performance in this work, the TiO_2 allows the photodegradation reaction occurred [34]. The photodegradation is a process of decomposing a compound (usually an organic compound) with a photon energy [35]. This reaction is based on the absorption of photons by photocatalysts with energies greater than their band-gap energies. The electron excites from a valence band to a conduction band. It creates an electron-hole pair. Following with the electrons adequate of migrating to TiO_2 catalyst. The electron-hole pair trigger the forming of hydroxyl radical and then react with the dye. The photocatalytic mechanisms of TiO_2 involved an oxidation, reduction and hydroxyl-radical attack [36]. This research in line with the research done by Agung et al [34] that suggested TDS value dropped in wastewater during a photocatalytic process with catalyst of TiO_2-ZnO. However, that study reported after the addition of 12 mg catalyst, concentration the TDS rejection started fluctuate due to unstable of water flowrate which conducted in continue reactor system.

Fig. 4 shows the conductivity has similar trend as TDS where it decreases with the increasing of TiO_2 concentration. The highest

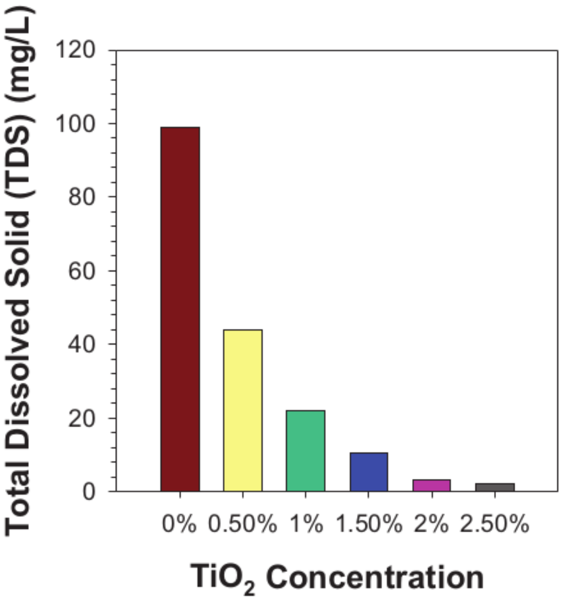

Fig. 3. Total dissolve solid (TDS) at various TiO_2 concentration.

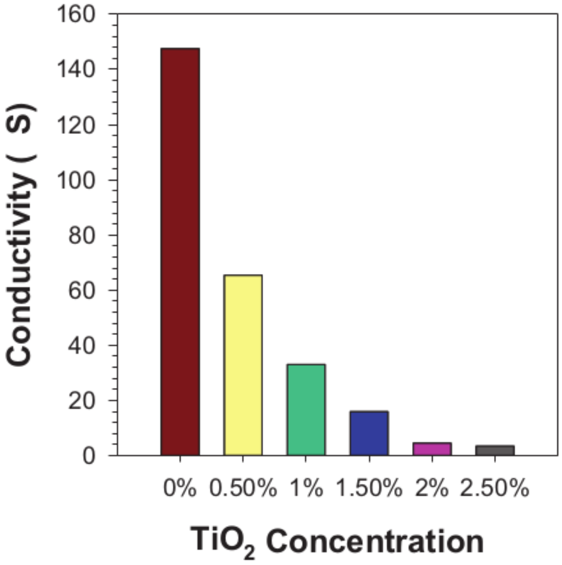

Fig. 4. Conductivity (μS) on various TiO_2 concentration.

conductivity at 0% catalyst was 147.56 μS and the lowest was 3.5 μS at 2,5% catalyst. Another research were conducted by Hubadillah et al[37], it shows a fair performance of bio-ceramic hollow fiber membrane for decreasing 31% of conductivity value in textile wastewater). Hubadillah et al[37] research has reported that the good performance achieved by combining the photocatalytic process and hollow fiber membrane. Desa et al[38] has investigated that a combination between photocatalytic and polymer membrane on MPR (membrane photocatalytic reactor) increase the conductivity removal of 92.38% from textile wastewater. The conductivity rejection happened regardless of the hazardous particle in textile wastewater is retained on the membrane surface. Interestingly, the higher membrane selectivity obtained when the foulant attached on the membrane pores, however there is a lack of water flux [16]. The photocatalytic process that decomposes the dye particle are influencing the membrane performance. The photocatalytic tends to make the membrane more selective and also enhance the reaction rate for catalyst TiO_2 to decrease the conductivity [39]. The conductivity from the permeation fulfiled the quality standard for textile wastewater [15].

4. Conclusion

Hollow fiber membrane with pervaporation – photocatalytic can be applied to process Sasirangan wastewater. The highest water flux of 4.3516 $kg.m^{-2}h^{-1}$ is obtained for 2.5% TiO_2 catalyst. These combining process achieves the colour rejection of 98.02%, TDS value of 2,345 mg/L, and conductivity of 3.5 μS for 2.5% TiO_2 catalyst. TiO_2 presences in the photocatalytic significantly decrease color, TDS, and conductivity. The photocatalytic could also reduce the membrane fouling.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] C. Irawan I.F. Nata M.D. Putra M. Elma K.F. Hanisa Biocomposite Materials of Eleocharis dulcis Fibers with Iron (III) Nanoparticles and Its Potential for Sasirangan Textile Wastewater Treatment 7 4 1234 10.18517/ijaseit.7.4.2425
[2] Y.M. Xu, S. Japip, T.-S. Chung, UiO-66-NH2 incorporated dual-layer hollow fibers made by immiscibility induced phase separation (I2PS) process for ethanol dehydration via pervaporation, Journal of Membrane Science 595 (2020) 117571.
[3] K. Khoiriah, D.V. Wellia, S. Safni, Degradation of diazinon pesticide by sunlight photocatalysis process using catalyst C, N-codoped TiO_2, Jurnal Kimia dan Kemasan 41 (1) (2019) 17–25.
[4] F. Parvizian, F. Ansari, S. Bandehali, Oleic acid-functionalized TiO2 nanoparticles for fabrication of PES-based nanofiltration membranes, Chemical Engineering Research and Design 156 (2020) 433–441.
[5] L. Lu, R. Shan, Y. Shi, S. Wang, H. Yuan, A novel TiO2/biochar composite catalysts for photocatalytic degradation of methyl orange, Chemosphere 222 (2019) 391–398.
[6] M. Elma, N. Riskawati, Marhamah, Marhamah, Silica Membranes for Wetland Saline Water Desalination: Performance and Long Term Stability, IOP Conference Series: Earth and Environmental Science 175 (2018) 012006, https://doi.org/10.1088/1755-1315/175/1/012006.
[7] M. Elma, Hairullah, Z.L. Assyaifi, Desalination Process via Pervaporation of Wetland Saline Water, IOP Conference Series: Earth and Environmental Science, IOP Publishing 175 (2018) 012009, https://doi.org/10.1088/1755-1315/175/1/012009.
[8] M. Elma, A. Sumardi, A. Paramita, A. Rahma, A.E. Lestari, D.H.Y. Yanto, S. Hadi, Z.L. Assyaifi, Sunardi, Y. Raharjo, Physicochemical Properties of Mesoporous Organo-Silica Xerogels Fabricated through Organo Catalyst, Membranes 11 (8) (2021) 607, https://doi.org/10.3390/membranes11080607.
[9] M. Elma, A.E. Lestari, A. Sumardi, Z.L. Assyaifi, A. Darmawan, D.R. Mujiyanti, I. Syauqiah, A. Rahma, L. Suciwati, Y. Mawaddah, Organo-Silica Membrane Prepared from TEOS-TEVS Modified with Organic-Acid Catalyst for Brackish Water Desalination, Jurnal Rekayasa Kimia & Lingkungan 16 (2) (2021) 11–18.
[10] M. Elma, E.L.A. Rampun, A. Rahma, Z.L. Assyaifi, A. Sumardi, A.E. Lestari, G.S. Saputro, M.R. Bilad, A. Darmawan, Carbon templated strategies of mesoporous silica applied for water desalination: A review, Journal of Water Process Engineering 38 (2020), https://doi.org/10.1016/j.jwpe.2020.101520 101520.
[11] M. Elma, H. Setyawan, Synthesis of Silica Xerogels Obtained in Organic Catalyst via Sol Gel Route, IOP Conference Series: Earth and Environmental Science, IOP Publishing 175 (2018) 012008, https://doi.org/10.1088/1755-1315/175/1/012008.
[12] M. Elma A.E. Pratiwi A. Rahma E.L.A. Rampun N. Handayani The Performance of Membranes Interlayer-free silica-pectin Templated for Seawater Desalination via Pervaporation Operated at High Temperature of Feed Solution 981 349 355
[13] A.E. Lestari M. Elma S. Rabiah E.L.A. Rampun A. Rahma A.E. Pratiwi Performance of Mesoporous Organo Silica Membrane for Desalination 1000 285 292
[14] A. Rahma, M. Elma, A.E. Pratiwi, E.L.A. Rampun, Performance of interlayer-free pectin template silica membranes for brackish water desalination, Membrane Technology 2020 (6) (2020) 7–11.
[15] A.E. Pratiwi, M. Elma, M.D. Putra, A. Mirwan, A. Rahma, E.L.A. Rampun, Innovation of Carbon from Pectin Templated in Fabrication of Interlayer-free Silica-Pectin Membrane, Jurnal Kimia Sains dan Aplikasi 22 (3) (2019) 93–98.
[16] A.E. Pratiwi, M. Elma, A. Rahma, E.L. Rampun, G.S. Saputro, Deconvolution of pectin carbonised template silica thin-film: synthesis and characterisation, Membrane Technology 2019 (9) (2019) 5–8.
[17] A. Sumardi, M. Elma, E.L.A. Rampun, A.E. Lestari, Z.L. Assyaifi, A. Darmawan, D.H.Y. Yanto, I. Syauqiah, Y. Mawaddah, L.S. Wati, Designing a mesoporous hybrid organo-silica thin film prepared from an organic catalyst, Membrane Technology 2021 (2) (2021) 5–8, https://doi.org/10.1016/S0958-2118(21)00029-X.
[18] M. Elma, H. Setyawan, A. Rahma, A. Pratiwi, E.L.A. Rampun, Fabrication of Interlayer-free P123 Caronised Template Silica Membranes for Water Desalination: Conventional Versus Rapid Thermal Processing (CTP vs RTP) Techniques, IOP Conference Series: Materials Science and Engineering, IOP Publishing (2019) 012076.
[19] S.K. Rahman, Fabrication and Application of Interlayer-Free Hybrid Membrane ES40 - P123 for Wetland Saline Water Desalination, Magister of Chemical Engineering Thesis, Universitas Lambung Mangkurat (2020).
[20] M. Elma, A. Fitriani, R.H. Rakhman, Silica P123 Membranes for Desalination of Wetland Saline Water in South Kalimantan, IOP Conference Series: Earth and Environmental Science, IOP Publishing (2018) 012007.
[21] M. Elma, G.S. Saputro, Performance of Cobalt-Silica Membranes through Pervaporation Process with Different Feed Solution Concentrations, Trans Tech Publ, Materials Science Forum, 2020, pp. 342–348.
[22] M.H. Abd Aziz, M.H.D. Othman, N.A. Hashim, M.R. Adam, A. Mustafa, Fabrication and characterization of mullite ceramic hollow fiber membrane from natural occurring ball clay, Applied Clay Science 177 (2019) 51–62.
[23] E. Pradhana, M. Elma, M. Othman, N. Huda, M. Ul-haq, E.L. Rampun, A. Rahma, The Functionalization Study of PVDF/TiO2 Hollow Fibre Membranes Under Vacuum Calcination Exposure, Journal of Physics: Conference Series, IOP Publishing (2021) 012035.
[24] M.-Y. Yang, J.-W. Wang, L. Li, B.-B. Dong, X. Xin, S. Agathopoulos, Fabrication of low thermal conductivity yttrium silicate ceramic flat membrane for membrane distillation, Journal of the European Ceramic Society 39 (2–3) (2019) 442–448.
[25] R. Bouchareb K. Derbal Y. Özay Z. Bilici N. Dizge Combined natural/chemical coagulation and membrane filtration for wood processing wastewater treatment Journal of Water Process Engineering 37 2020 101521 10.1016/j.jwpe.2020.101521
[26] S. Waqas, M.R. Bilad, Z.B. Man, H. Suleman, N.A.H. Nordin, J. Jaafar, M.H.D. Othman, M. Elma, An energy-efficient membrane rotating biological contactor for wastewater treatment, Journal of Cleaner Production 282 (2021) 124544.
[27] T.J. Mohammed, H.A. Al-Zuheri, Application of response surface methodology for analysis and optimization of the operational parameters for turbidity removal from oily wastewater by electrocoagulation process, IOP Conf. Ser, Mater. Sci. Eng. (2018) 1–13.
[28] U. Santoso, E.S. Mahreda, F. Shadiq, D. Biyatmoko, Sasirangan wastewater treatment through a combination of filtration methods and phytoremediation

of artificial wetland systems using different aquatic plants, EnviroScienteae 10 (3) (2016) 157–170.

[29] N. Nasruddin, D. Nurandini, B. Halang, R. Kumalawati, S. Syaharuddin, S. Riadi, N., Farista Aristin, Identification of Potential Liquid Waste of Sasirangan Dyes on, Pollution in Banjarmasin City, LPPM ULM, 2018.

[30] A. Maljaei, M. Arami, N.M. Mahmoodi, Decolorization and aromatic ring degradation of colored textile wastewater using indirect electrochemical oxidation method, Desalination 249 (3) (2009) 1074–1078.

[31] D.K. Wang, M. Elma, J. Motuzas, W.-C. Hou, F. Xie, X. Zhang, Rational Design and Synthesis of Molecular-sieving, Photocatalytic, Hollow Fiber Membranes for Advanced Water Treatment Applications, Journal of membrane science 524 (2017) 163–173.

[32] A.J. Kajekar, B. Dodamani, A.M. Isloor, Z.A. Karim, N.B. Cheer, A. Ismail, S.J. Shilton, Preparation and characterization of novel PSf/PVP/PANI-nanofiber nanocomposite hollow fiber ultrafiltration membranes and their possible applications for hazardous dye rejection, Desalination 365 (2015) 117–125.

[33] S. Notodarmodjo, S. Gustiani, C. Radiman, M. Syafila, Effect of Fouling on Bacterial Cellulose Nano Fiber Membrane Surface With Nanoparticles Ag And TiO_2, Arena Tekstil 31 (1) (2016).

[34] T. Agung, M.D. Darmawan, Linear Provision Of Alklybenzene Sulfonate (Las) And Total Dissolved Solid (Tds) Using A Photocatalyst Process With Combination Of Catalyst TiO_2-ZnO, ENVIROTEK: Jurnal Ilmiah Teknik Lingkungan 12 (1) (2020) 35–43.

[35] Z.L. Assyaifi, M. Elma, I. Syauqiah, E.L. Rampun, A. Rahma, A. Sumardi, A.E. Lestari, L. Suryani, F.R. Mustalifah, N. Huda, Photocatalytic–pervaporation using membranes based on organo-silica for wetland saline water desalination, Membrane Technology 2021 (7) (2021) 7–11.

[36] E. Marlina, S. Goh, T. Wu, T. Tan, S.B. Abd Hamid, J.C. Juan, Evaluation on the Photocatalytic Degradation Activity of Reactive Blue 4 using Pure Anatase Nano-TiO2, Sains Malaysiana 44 (2015) 1011–1019. https://doi.org/10.17576/jsm-2015-4407-13.

[37] S.K. Hubadillah, M.H.D. Othman, Z.S. Tai, M.R. Jamalludin, N.K. Yusuf, A. Ahmad, M.A. Rahman, J. Jaafar, S.H.S.A. Kadir, Z. Harun, Novel hydroxyapatite-based bio-ceramic hollow fiber membrane derived from waste cow bone for textile wastewater treatment, Chemical Engineering Journal 379 (2020) 122396.

[38] A.L. Desa, N.H.H. Hairom, L.Y. Ng, C.Y. Ng, M.K. Ahmad, A.W. Mohammad, Industrial textile wastewater treatment via membrane photocatalytic reactor (MPR) in the presence of ZnO-PEG nanoparticles and tight ultrafiltration, Journal of Water Process Engineering 31 (2019) 100872.

[39] D. Sugiyana, Y. Harja, Photocatalytic Decolorization of Textile Wastewater Containing Azo Acid Red 4 Color Substances Using Microparticles TiO_2 and ZnO, Arena Tekstil 29 (1) (2016).

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