



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

Isnasyauqiah<sup>a,b</sup>, Muthia Elma<sup>a,b,\*</sup>, Eggy A. Pradana<sup>a,b</sup>, Muhammad D. Ul-haq<sup>a,b</sup>, Erdina L.A. Rampun<sup>b</sup>, Aulia Rahma<sup>b</sup>, Awali S.K. Harivram<sup>a,b</sup>, Zaini L. Assyaifi<sup>b</sup>, Yayan Kamelia<sup>a</sup>

<sup>a</sup>Chemical Engineering Department, Engineering Faculty, Lambung Mangkurat University, Jl. A. Yani KM 36, Banjarbaru, South Kalimantan 70714, Indonesia

<sup>b</sup>Materials and Membranes Research Group (M<sup>2</sup>ReG), Lambung Mangkurat University, Jl. A. Yani KM 36, Banjarbaru, South Kalimantan 70714, Indonesia

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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<sub>2</sub> 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<sup>-2</sup>.h<sup>-1</sup> as well as good rejection in color of 98.02%, TDS of 2.345 mg/L, and conductivity (3.5μS) for 2.5% TiO<sub>2</sub>. 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<sub>2</sub>) due to its abundance, effective, stable against photo corrosion, non-toxic to the humans and environment[3]. The TiO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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

\* Corresponding author.

E-mail address: [melma@ulm.ac.id](mailto:melma@ulm.ac.id) (M. Elma).

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  $\text{TiO}_2$  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 ( $\text{TiO}_2$ ) for analysis Merck, The PVDF- $\text{TiO}_2$  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- $\text{TiO}_2$ 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.  $\text{TiO}_2$  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

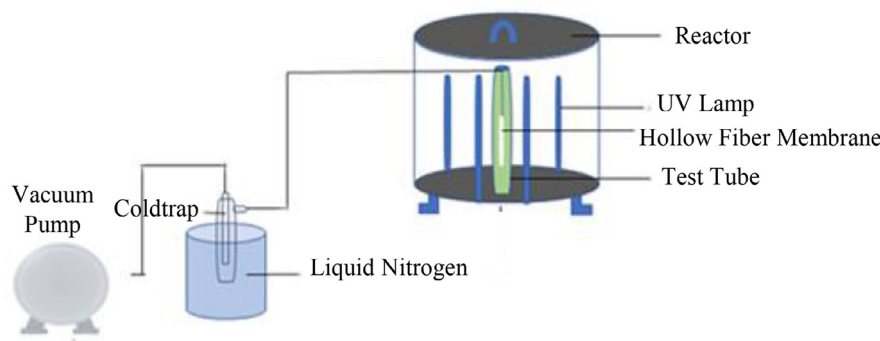
**Table 1**  
Characteristic of Sasirangan wastewater.

| Parameter                    | Sample value | Quality standard South Kalimantan Governor Regulation No.36/2008 | Unit             |
|------------------------------|--------------|--|------------------|
| Color (UV <sub>380</sub> nm) | 0.76         | –  | cm <sup>-1</sup> |
| Turbidity                    | 74.7         | 1–5  | NTU              |
| TDS (total dissolve solid)   | 118.27       | ≤ 2000   | mg/L             |
| Conductivity                 | 176.53       | 400  | μS               |

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, conductivity 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.

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<sup>-1</sup> 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<sup>-2</sup>h<sup>-1</sup> at 2.5%  $\text{TiO}_2$  catalyst. Furthermore, the colour rejection was increased along with the  $\text{TiO}_2$  concentration rises. The enhancing of  $\text{TiO}_2$  concentration on photocatalysis has been affected to increasing of parameters rejection (colour). As the adding of  $\text{TiO}_2$  concentration from 0.5 to 2.5 %  $\text{TiO}_2$ , the colour rejection also increases (Fig. 2). However, this result is contradicted to Khoiriah, Wellia and Safni [3] work, which states as loading of  $\text{TiO}_2$  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  $\text{TiO}_2$  concentration is only 0–2.5 %, that exhibits increasing performance



**Fig. 1.** Pervaporation-photocatalytic set-up.

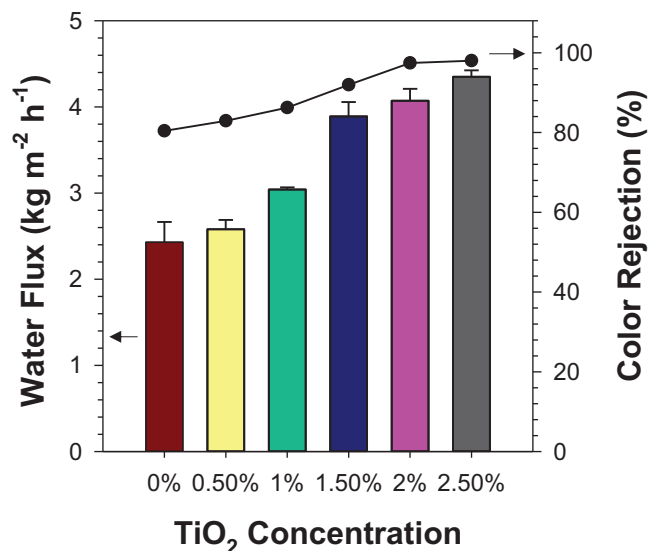


Fig. 2. Pervaporation-photocatalytic performance of hollow fiber membranes for Sasirangan wastewater based on water flux and colour rejection.

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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> addition. The TiO<sub>2</sub> 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<sub>2</sub> to a membrane matrix enhanced the hydrophilicity material and selectivity [31]. Notodarmodjo et al [33] has stated that TiO<sub>2</sub> 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<sub>2</sub> concentration added. Then, there would be a decrease in the permeate flow.

Fig. 3 demonstrates the TDS rejection in Sasirangan wastewater after the TiO<sub>2</sub> 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<sub>2</sub> 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

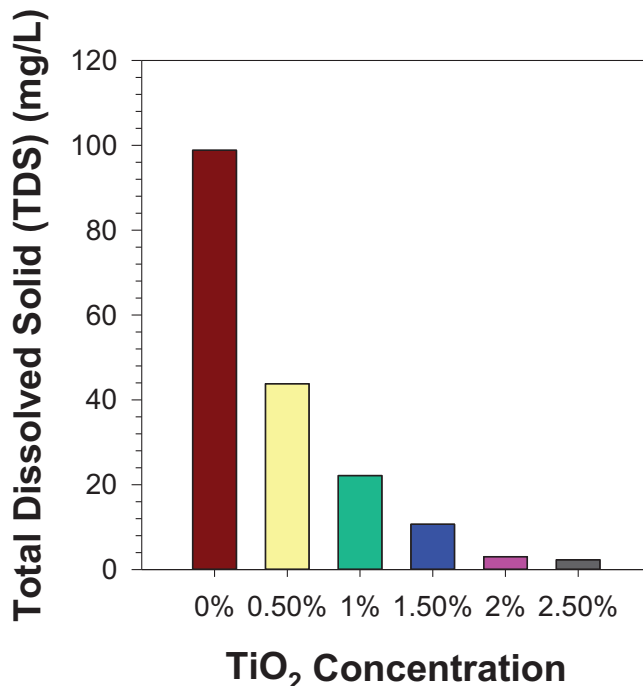


Fig. 3. Total dissolve solid (TDS) at various TiO<sub>2</sub> concentration.

electrons adequate of migrating to TiO<sub>2</sub> catalyst. The electron-hole pair trigger the forming of hydroxyl radical and then react with the dye. The photocatalytic mechanisms of TiO<sub>2</sub> 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<sub>2</sub>-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<sub>2</sub> concentration. The highest

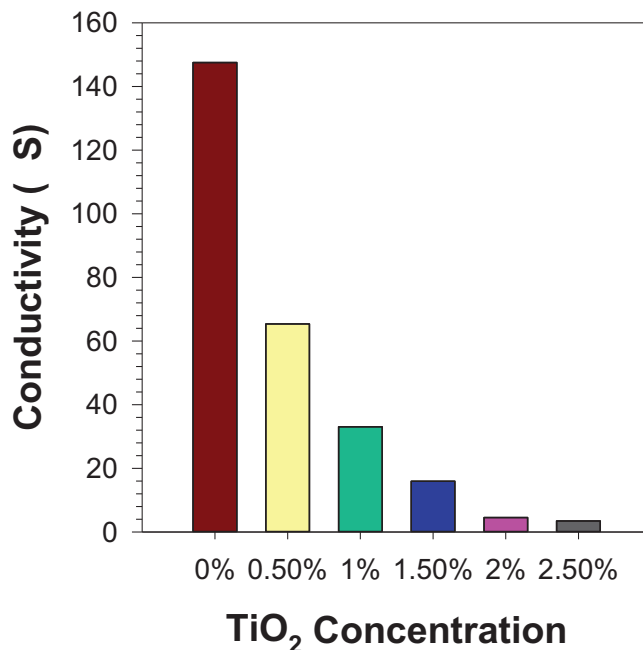


Fig. 4. Conductivity (µS) on various TiO<sub>2</sub> concentration.

conductivity at 0% catalyst was 147.56  $\mu\text{S}$  and the lowest was 3.5  $\mu\text{S}$  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  $\text{TiO}_2$  to decrease the conductivity [39]. The conductivity from the permeation fulfilled 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  $\text{kg}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$  is obtained for 2.5%  $\text{TiO}_2$  catalyst. These combining process achieves the colour rejection of 98.02%, TDS value of 2,345 mg/L, and conductivity of 3.5  $\mu\text{S}$  for 2.5%  $\text{TiO}_2$  catalyst.  $\text{TiO}_2$  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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