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Performance of Nanofiltration Membrane for Printing Wastewater Treatment

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ABSTRACT

Almost every manufacturing process is the major origin of wastewater with certain characteristic. Printing facility provides a wide range of waste component that is harmful to the environment and people. Those harmful waste component contains high concentration of heavy metals and dye. This paper presents one of the most promising methods to remove the heavy metals and dyes from a printing wastewater before discharging to the environment. The feasibility of commercially available NF270 membrane to treat both heavy metals and dye was thoroughly investigated. The study was carried out using a cross-flow nanofiltration membrane system at operating pressure and temperature set at 5 bar and 24 ˚C, respectively. Experimental results showed that the permeate flux of NF270 is decreased from 6.2 to 5.0 L/m^2.h after 1-h operation. Whilst, the rejection of both iron and zinc ions could be obtained up to 96.9% and 97.8%, respectively. Additionally, almost complete elimination of colour (99.6%) could be achieved using NF270 membrane. Thus, it can be concluded that the commercial NF270 membrane is promising in removing both heavy metal ions and dye from printing wastewater.

Keywords: Printing wastewater treatment, thin film nanocomposite, nanofiltration

1.0 INTRODUCTION

The survival of humanity has improved over the last few decades, from merely social reproduction to the development of human sustainability. Social sustainable evolution entails as wide as improvise in the comfortability, functionality, and versatility that permeated through all class of the societies. While the human lifestyle continues sophisticating in various aspects thanks to expeditious industrialization and economic growth globally, the activities also causing drastic adversity to the environment and living organism in the world. The impacts include depletion of non-renewable resources, threatening the survivability of the ecosystem, heavy pollution to environment, and eventually leads to backlash on human lifespan. One of the major contributor in polluting the environment is printing industry [1-2].

In printing industries, there are two types of ink production: water-based printing ink and solvent-based printing ink. Water is used as carrier in water-based printing ink production while organic solvent is used as carrier in solvent-based printing ink. Unlike organic solvent, water is less volatile hence it does not produce any abhorrent vapor during production. Packaging industry prefers using water-based ink to print advertisements and information on their packaging. Water-based printing ink has been receiving a lot of attention in recent years as their annual

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ink consumption increment is ranging 10% to 50% [3].

Other than using water as carrier in production of ink, water is also used in cleaning the equipment before changing different tone of ink. This wastewater contains very high concentration mixture of color pigment, organic solvents, and heavy metal [1]. Every printing companies have their own method in production and different set of tone required, therefore every printing industries wastewater is different from each other.

Table 1 presents the example of characteristic of printing wastewater from three different industries. Another dangerous element from the wastewater that threaten the environment is synthetic dyes. It also known as the most challenging component to treat in wastewater because it contains complex benzoic molecular structure, which make them difficult to decompose and high chemical resistance. Besides, synthetic dyes have various types according to their chemical compound. But most of the dyes able to break down their chemical structure if heated up to 473.15K [4-5].

Table 1 Characteristic of printing wastewater from various industries

Company	**-**	**Singhal Brothers**	**UMWW**
Bussiness	**Currency printing**	**Textile dye**	**Newspaper Printing**
pH	12.5-13.6	10.41	8.0 ± 0.3
Colour	Intense blue (3000-4000 Pt-Co)	Black	2406 7.0 APHA
BOD (mg/L)	8000-9400	-	-
COD (mg/L)	21000-25650	4661	1099 ± 3.0
TSS (mg/L)	3300-4700	-	92.8 ± 3.0
TDS (mg/L)	18000-22500	103000	-
Reference	[9]	[7]	[10]

Like printing industries, textile dyeing industries also uses water immensely in their dyeing and finishing process. Their dyeing wastewater also heavy in color and chemicals. Thus, all these industrial wastewaters require a proper treatment before they allow to discharge to the environment [6]. If the effluents did not filter before discharge into river or any groundwater, it would jeopardize the aquatic environment. Toxic elements such as heavy metal would consume by the aquatic organisms and eventually reach to human body via bioaccumulation [7].

To treat industrial wastewater, application of membrane technologies is increasingly in demand because this technology helps in retains and recovers some valuable components in the wastewater as well as reuse the aqueous solution after treatment [6]. Among the membrane technologies, ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) are the most commonly used technologies. Industrial application of nanofiltration is emerging into the limelight recently in the wastewater treatment field [8].

The reason NF getting more attention than the other membrane technologies is because NF able to operate under lower pressure than RO, thus required less energy to operate, and it has higher rejection rate compare to UF. As of now, NF is widely used to separate multivalent ionic compound with relatively low molecular weight (200-1000 $gmol^{-1}$) from wastewater [6, 8]. Heavy metal such as iron and zinc are the example of metallic multivalent ionic compound. Thus, the objective of this study is to investigate the performance of NF270 in treating printing wastewater that contain heavy metals and dyes.

2.0 METHODS

2.1 Materials

Commercially available NF270 was purchased from Dow Filmtech Corporation. The wastewater obtained from UMWW Corporation, a company who expertise in printing and publication of newspaper. The volume of wastewater collected is 9.5 L and light blue in color. Table 2 shows the characteristic of the wastewater given from UMWW Corporation at 24℃.

Table 2 Characteristic of wastewater from UMWW Corporation

Chemical properties	Value
COD (mg/L)	1100
Turbidity (FAU)	343.5
TSS (mg/L)	93.4
pH	8.2
Color intensity (APHA)	2412

2.2 Characterization of NF270

The morphology of the NF270 was examined by using Scanning Electron Microscopy (SEM) analysis with an accelerating voltage of 20.0 kV. Atomic force microscopy (AFM) was used to characterize the surface morphology of the NF270 in terms of the roughness parameters. The scanning area of each membrane was 5µm × 5µm.

2.3 NF Membrane Performance Evaluation

The flux and rejection of the fabricated NF270 membrane was studied using a crossflow NF system as shown in Figure 1. The NF270 membrane was initially compacted at a trans-membrane pressure difference of 6 bar with DI water for about 1 h. The effective membrane surface area was 42 cm^2. The NF experiments were then performed using printing wastewater at an operating pressure and temperature set at 5 bar and 24 ˚C, respectively.

Membrane water flux (F) was subsequently calculated using the following equation:

$$F = \frac{V}{t \times A} \quad (1)$$

Where V is the permeate volume (L), A is the membrane area (m^2) and t is the time to obtain V (h).

Whereas, both heavy metals and dyes rejection were then determined using the following equation

$$R(\%) = (1 - \frac{C_p}{C_f}) \times 100 \quad (2)$$

where C_p is the permeate concentration (ppm) and C_f is the feed concentration (ppm), respectively.

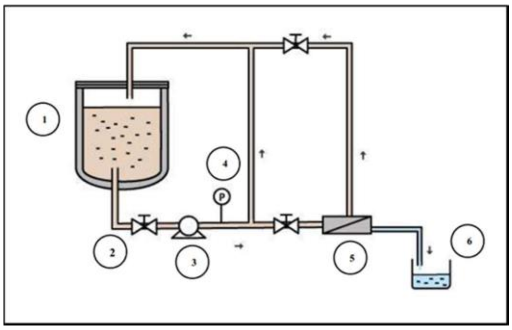

Figure 1 Schematic diagram of membrane nanofiltration process

An ICP-OES spectrometer (Optima 8000) was used to measure the heavy metals ion concentration in the feed and permeate solutions. While an UV-Vis Laboratory spectrophotometer (DR 5000) at a wavelength of 192 nm was used to measure the dye concentration in the feed and permeate solutions

3.0 RESULTS AND DISCUSSION

3.1 Characteristic of Membrane NF270

The 3D image of NF270 was presented in Figure 2 with an average surface roughness value of 8.69 nm. A common ridge and valley structure could be observed on the surface of NF 270 membrane. Likewise, this structure has also been observed on the SEM image shown in Figure 3.

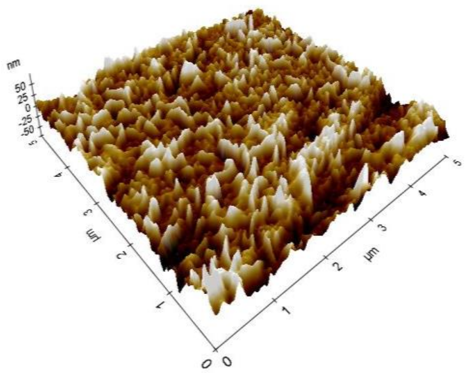

Figure 2 3D AFM image of NF270

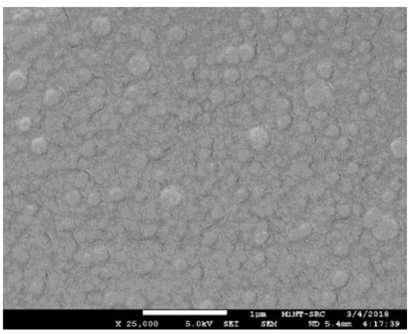

Figure 3 SEM surface image of NF270

3.2 Permeation Flux of NF270

As can be depicted from Figure 4, the permeate flux was gradually decreased from 6.286 LMH to 5.017 LMH as the time increased. This mainly due to the formation of membrane fouling on top of the membrane surface. When the pores of membrane started to block by foulants, the permeate flux plummeted down sharply. After 30 minutes, foulants start to aggregate each other and the development of rapid cake formation occurs, and thus, the permeate flux decline relatively constant [11, 12, 13].

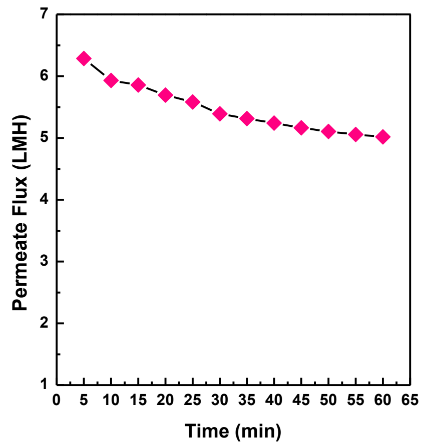

Figure 4 Permeate flux of NF270

3.2 Heavy Metal Ions Rejection of NF270

It was detected that the printing wastewater contains Iron (Fe) ion and Zinc (Zn) ion. The initial feed concentration of Fe ion and Zn ion were 15.8082 mg/L and 14.956 mg/L, respectively. After treated with membrane nanofiltration process, the concentration of both ions were decreased tremendously. Fe ion concentration in treated water is ranging from 0.333 mg/L to 0.342 mg/L. Whereas, Zn ion concentration in treated water is ranging from 0.473 mg/L to 0.459 mg/L. Thus, the heavy metal ions rejection could be achieved up to 96.93% for Fe ion and 97.79% for

Zinc ion at an operating time of 1 hour, as can be seen in Figure 5. NF270 has negative surface charge that able to attract any positive ion such as iron ion and zinc ion. This attraction with the steric effect causing the ions attached on the membrane surface without passing through. As soon as the accumulation of heavy metal ions increase, the membrane is topped with a layer of positive charged ion. This positive charged ion will aid the membrane in preventing other positive heavy metal ion to approach the membrane [13].

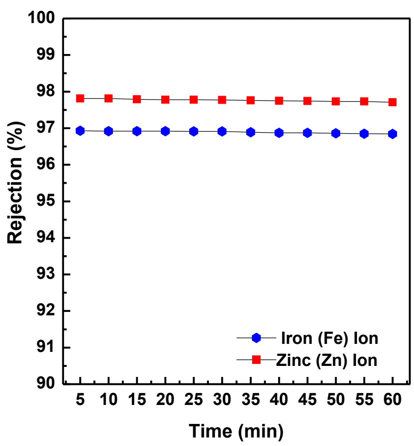

Figure 5 Heavy metal ions rejection at an operating pressure of 5 bar and operating time of 60 minutes

3.2 Dye Rejection of NF270

Figures 6 shows the rejection of dye during 60 minutes of operating time. The dye rejection increased gradually from 96.4% to 99.6%. This may probably due to the membrane pore blockage by foulants which subsequently, increased the rejection of dyes when increased the operating times [10, 11, 12].

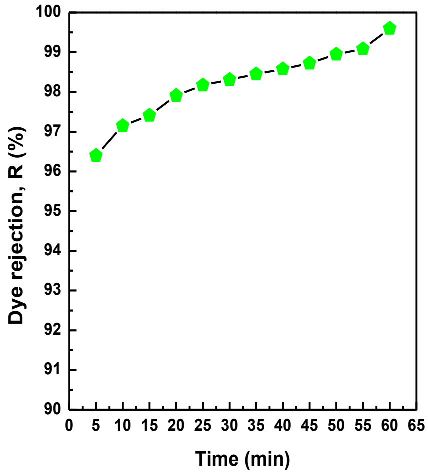

Figure 6 Dye rejection at an operating pressure of 5 bar and operating time of 60 minutes.

4.0 CONCLUSION

The permeate flux decreased from 6.3 LMH to 5.02 LMH after 1 hour of operating time. This is mainly due to membrane fouling that plays a major causative agent in decline of permeate flux during filtration process. Whilst, the rejection rate of nanofiltration process is very promising with 96.93% of iron ion rejection, 97.79% of zinc ion rejection, and 99.64% of dye rejection rate. Thus, it is the nanofiltration membrane process is a highly recommended method for treating industrial printing wastewater as it has high rejection rate for both heavy metals and dyes with a driving pressure much lower than reverse osmosis.

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