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Benzene and Toluene Removal from Saline Water with Coupled Membrane Process and Nanophotocatalyst

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INTRODUCTION

The increase in unnecessary consumption due to advances in the industry has caused environmental destruction. Untreated wastewater is the main environmental pollutant. If wastewater does not properly clean and dispos in accordance to regulation, it will cause a severe pollution of the environment [1].

Polyaromatic hydrocarbons include compounds with two or more aromatic rings. Moreover, polyaromatic hydrocarbons are carcinogenic and resistant compounds in environment which pollutants water, air, and soil [1].

Over the last decade, forward osmosis (FO) has been considered by various researchers as an energy-efficient and economical alternative to conventional seawater desalination technologies. Forward osmosis (FO) is the induction of a net flow of water from a low-concentration feed solution (FS) to a high-concentration draw solution (DS) through a semipermeable membrane [2]. Moreover, the process is driven by the osmotic pressure gradient across the membrane. Membrane processes are effective methods to remove different water contaminants which have significant adverse effects on the health and environment. However, the membrane has many advantages in the contaminants separation, but the pollutants are not eliminated. For this reason, it is very desirable to combine other contaminant removal mechanisms with membrane processes. In addition, this hybrid system can adequately separate and remove most of the pollutants from water. So far, just a few photocatalytic studies have been conducted on the modified FO membrane with TiO_2 for water treatment. Moreover, titanium dioxide is the most commonly used photocatalyst in water treatment due to its high removal efficiency, cost-effectiveness, chemical stability, and low toxicity. TiO_2 is able

to completely decompose organic pollutants into carbon dioxide water. The incorporation of TiO_2 nanoparticles into a water filtration membrane has been found to enhance its flux, contaminant removal, and fouling resistance [3].

Therefore, in this study, for the first time, the membrane with photocatalyst has been performed in forward osmosis process. In addition, the hydrophilicity of the membranes has been investigated with flux and contact angle. The flux changes have been investigated in three types of CTA, PES, and CTA with TiO_2. Moreover, the efficiency of the hybrid system in the removal of hydrocarbon contaminants has been studied.

EXPERIMENTAL PROCEDURE

FO system performance and transport properties evaluation of the membranes

To investigate the FO (forward osmosis) membranes efficiency, water flux and salt flux have been determined in a laboratory-scale FO setup (Figure 1). The unit includes two chambers with dimensions of 12 cm length, 8 cm width, and 1 cm depth, giving the effective membrane area of about 96 cm^2 in both sides. The cell has been operated with the co-current cross flow. Moreover, two diaphragm pumps (Headon, 1.6 LPM) with the same flow (800 $ml.min^{-1}$) have been used for the circulation of the feed and draw solutions. In this study, NaCl solution (67,139 and 181 $gr.l^{-1}$) has been used as draw solution (DS). The concentrations of Benzene and toluene in the feed solution (FS) with the salinity of 35 $gr.l^{-1}$ have been 5 and 10 $mg.l^{-1}$.

In this study, two feed solution (distilled water and synthetic water) and a draw solution (non-ionic surfactant TX-100) have been used for better efficiency and minimizing reverse salt flux.

RESULTS AND DISCUSSION

To assess the effectiveness of the membrane surface, Scanning Electron Microscopy (SEM) analysis of the samples has been conducted using a MIRA3TESCAN-XMU microscope to characterize the three membranes (Figure 2).

This observation confirms that the hydrophilic TiO_2, TiO_2/GO additives proceed to the top layer of the membrane since the top surface is more exposed to water. The presence of TiO_2 and TiO_2/GO on membrane surface improve the membrane hydrophilicity because of hydrophilic functional groups. Moreover, the EDX mapping of Ti element reveals the uniform dispersion of TiO_2 in the membrane surface [4-5].

The flux variation of different membranes are presented in Figure 3.

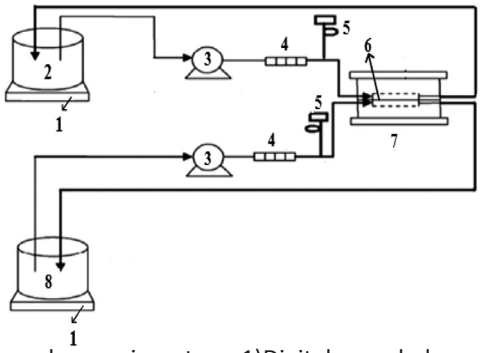

Figure1: Schematic diagram of forward osmosis system: 1)Digital mass balance, 2)Feed solution, 3)Pump, 4)Flow meter, 5)pressure gauge, 6)membrane, 7)FO membrane cell, 8)Draw solution.

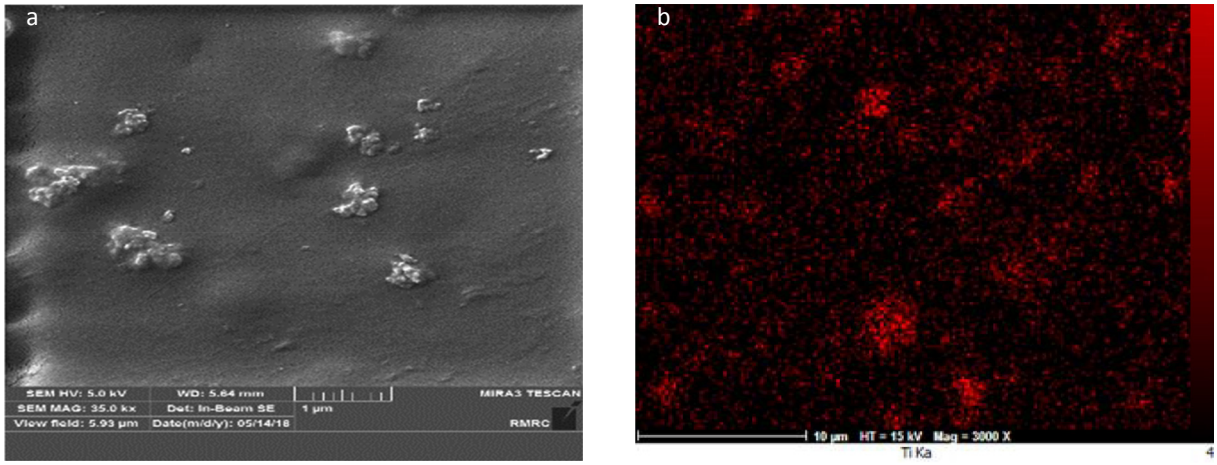

Figure 2: a) SEM image and b) EDX analysis of PES/TiO_2 membrane surface.

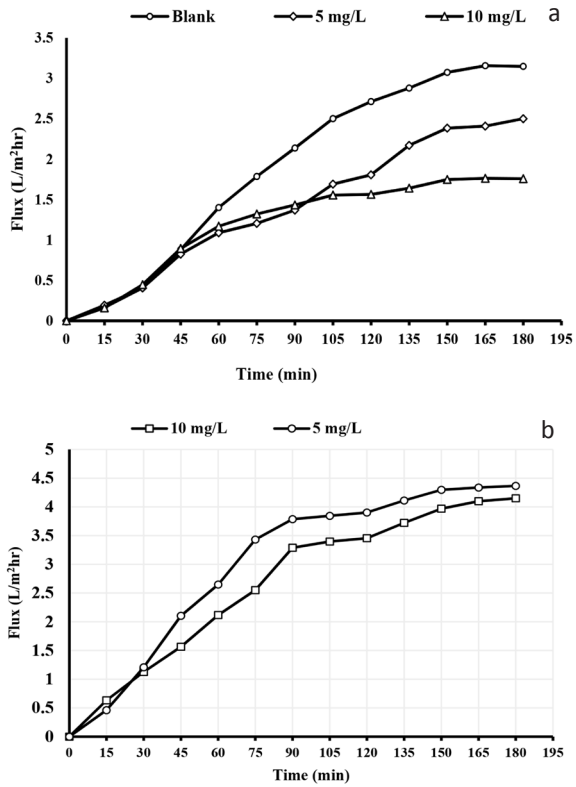

Figure 3: FO water flux with different BT concentration in the feed solution, a) CTA and b) CTA/TiO_2 membranes

As shown in Figure 3, the pure water flux has been increased in the CTA/TiO_2 under UV in comparison with the CTA membrane. The high permeability of the CTA/TiO_2 and CTA/TiO_2/GO membranes can be related to their high hydrophilicity [4].

The removal efficiency of Benzene and Toluene in the hybrid system is shown in Figure 4.

According to the results, with combining forward osmosis with photocatalyst, a significant portion of aromatic hydrocarbons has been reduced [4].

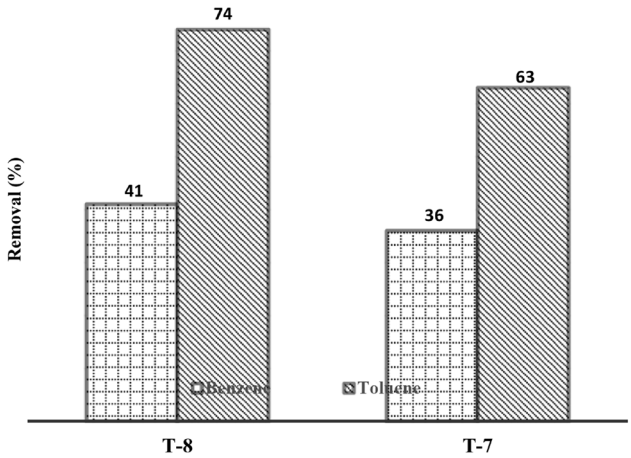

Figure 4: Removal efficiency of Benzene and Toluene.

CONCLUSION

The results of this study show that the hybrid system exhibit significant ability in waste water treatment. Several properties of CTA membrane have been improved with TiO_2 photocatalyst, including the effective photodegradation of polyaromatic hydrocarbons (BT) contaminants under UV, enhanced contaminant removal by photodegradation, and improved membrane flux due to photocatalysis increase hydrophilicity.

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