Fabrication of nanofiltration membranes based on polyethersulfone and modified with silica and carbon nanofillers to increase the efficiency of flux and treatment of pollutants from wastewater

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Abstract

Nanofiltration technology is a type of pressure-based membrane process that has been considered due to its cost and environmental Compatibility to remove organic dyes, heavy metals, and salts from the wastewater. In this study, nanofillers of PMO-PPD silica and carbon CQDs were used in the fabrication of membranes to compare their efficiency in the nanofiltration system. By successful analysis of FE-SEM, TEM, XRD, FTIR, contact angle (Bare PES = 63, nanofillers of PMO-PPD = 53.2 and CQDs = 56.4 $^{\circ}$), porosity (Bare PES = 66.7, nanofillers of PMO-PPD = 76.3 and CQDs = 74 %), and measurement of pore radius (Bare PES = 3.68, nanofillers of PMO-PPD = 5.13 and CQDs = 05.05 nm), the successful synthesis of nanofillers and their presence in the fabricated membranes were confirmed. Fabricated membranes with a weight percentage of 0.5 % with values of 47.1 and 43.8 L/M^{2}h for PMO-PPD and CQDs nanofillers, respectively, higher flux than membrane without nanofillers (PES Bare) with a value of 17.6 L/M^{2}h and show better hydrophilicity of these nanofillers. Antifouling parameters showed that both nanofillers improved the antifouling properties of the membrane. Removal rate of contaminants were for the membranes of Bare PES (21.5 % NaCl, 61.5 % MO, and 63.2 % Pb), PES-PMO-PPD 0.5 wt.% (24.8% NaCl, 85.2 % MO, and 1 71.1 % Pb), and PES-CQDs were 0.5 wt.% (27.93 % NaCl, 72.93% MO, and 89.76% Pb). The percentage of contaminant removal in nanofiller membranes was higher than PES Bare. The different characteristics of flux, antifouling, and removal of contaminants from the wastewater for comparison of PMO-PPD and CQDs nanofillers were due to the difference in the type of functional groups in these two nanofillers. The results showed that the fabricated membranes for nanofiltration technology were very effective in improving the flux and removing contaminants from the wastewater.

Keywords: Technology, Flux, PMO-PPD, CQDs, Antifouling

1. Introduction

Lack of clean water due to environmental pollution caused by the rapid growth of industry, infrastructure and climate change has been raised as a serious challenge [1]. With the rapid growth of industries and population growth around the world, many pollutants, including organic dyes, heavy metals and salts, are discharged into rivers and lakes and pose a serious threat to health and water pollution [2]. Synthetic dyes are a large group of chemicals used in industries such as textiles, leather, paper, pharmaceuticals, dyes, cosmetics, and more. Colored wastewater are discharged to surface waters without proper treatment and will cause adverse changes such as reduced light saturation, limited growth of aquatic plants, adverse effects on aquatic life, mutagenesis and cancer [3-5]. Heavy metals and salt contaminants can also cause environmental problems when discharged to surface and groundwater sources, even at low concentrations. The use of wastewater containing these pollutants without careful management can lead to adverse environmental consequences, including soil salinization, soil degradation, poisoning, reduced crop yields

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and pollution of surface and groundwater resources. Salt wastewater are also produced by many industries, including food processing plants, leather industries and oil refineries [6-8]. Heavy metals are naturally present in low concentrations in soil and rocks, but human activities such as industry, traffic, burning fossil fuels, and agriculture increase and propagate them to the environment and thus threaten biological life [9, 10]. Heavy metal removal is one of the most important concerns in wastewater treatment. Because they are toxic, resistant to biodegradation, and have a high tendency for bioaccumulation in living organisms and cause serious health problems [11]. Therefore, the removal of these pollutants from the wastewater as an important issue in controlling pollution and water treatment and meeting the growing global demand for clean water should be considered using new water treatment technologies [12]. Nanofiltration technology is used as a type of pressure-based membrane process, usually due to its cost, high efficiency, mild conditions and environmentally friendly characteristics in wastewater treatment. In particular, nanofiltration has excellent properties under selective conditions for the removal of some organic dyes, salt ions and heavy metals due to the separation of physical separation, electrostatic interaction and Donan deviation [2]. The high pressure nanofiltration membrane process is capable of producing large amounts of high quality water. Excellent contaminant removal capacity, reduced membrane cost, reduced energy consumption and increased membrane life compared to reverse osmosis have made nanofiltration widely accepted and popular all over the world. Therefore, the aim of this study was to fabricate PES-based nanofiltration membranes modified with PMO-PPD silica and carbon CQDs to increase flux efficiency and remove contaminants such as methyl orange (MO) dye, sodium chloride (NaCl) and heavy metal lead from the wastewater.

2. Materials and methods

In this study, PMO nanoparticles were first synthesized and functionalized with PPD functional group. Then the synthesis of CQDs nanoparticles was performed using the easy pyrolysis method. In the next step, membranes were fabricated using PMO-PPD and CQDs nanofillers with weight percentage to weight of PES polymer to DMAc solvent. The characterization of synthesized nanofillers and fabricated membranes was also reviewed and approved. The performance of nanofiltration membranes using a filtration device to remove contaminants was investigated.

3. Results and discussion

The FE-SEM image showed the surface morphology of PMO-PPD nanofillers as rope-shaped units and the TEM image showed nanofiller CQDs as uniform spherical points. The XRD pattern confirmed the functionalization of PMO nanoparticles with PPD group and FTIR analysis confirmed the presence of amino hydrophilic groups in PMO-PPD nanofiller and carboxyl and hydroxyl in CQDs nanofiller. The FE-SEM image showed the top surface of the membranes smooth and without compaction of the nanofillers, with an asymmetric structure with a dense top layer and a porous bottom layer for the cross section of the membranes. Also, by adding nanofillers with a weight percentage of 0.5%, they reduced the contact angle analysis, and increased the porosity and radius of the cavities, which in turn increased the pure water flux for both nanofillers. The difference in the percentage of contaminant removal in PMO-PPD and CQDs nanofillers was due to the difference in the type of functional groups in which the percentage of contaminant removal in fabricated membranes with nanofillers was higher than PES Bare membrane.

4. Conclusions

In this study, PMO-PPD silica nanofillers and carbon CQDs successfully increased membrane nanofiltration efficiency, which can be used for a variety of environmental applications, including the treatment of salt, dye and heavy metals pollutions from wastewater. Therefore, this technology can be used in industrial projects such as desalination units, textile industry, leather and paper industry, water and sewage companies because of its economic cost (reducing the cost of materials in the manufacture of membranes and providing nanofiltration system).

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