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ORIGINAL RESEARCH

Synthesis, characterization, and anti-fouling properties of cellulose acetate/polyethylene glycol-grafted nanodiamond nanocomposite membranes for humic acid removal from contaminated water

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Abstract
Polyethylene glycol-grafted nanodiamond (ND-PEG) was synthesized from pristine detonation NDs and utilized to prepare novel cellulose acetate/polyethylene glycol-grafted nanodiamond(CA/ND-PEG)nanocomposite membranes. Due to unique thermal, mechanical, and antibacterial properties and very easy cleaning of fouled ND-embedded CA nanocomposite membranes, we tried to investigate the performance of CA/ND-PEG membrane for humic acid (HA) removal from contaminated water. Surface functionalization was confirmed by Fourier transform infrared spectroscopy and thermogravimetry analysis. Pristine and functionalized ND with different concentration was added in the casting solution containing CA. The prepared membranes were characterized using contact angle, mechanical strength, scanning electron microscopy (SEM), transmission electron microscopy, and permeation tests. SEM micrographs of the surface of the membranes depicted the increase in the number of pores by the addition of ND and especially ND-PEG into polymer matrix. The results indicated that the nanocomposite membrane with 0.5 wt% ND-PEG exhibited excellent hydrophilicity, mechanical properties, permeability, high rejection, high abrasion resistance, and good anti-fouling performance. The HA adsorption on the membrane surface decreased from 2.85 to 2.15 mg cm^{-2} when the ND-PEG content increased from 0 to 0.5 wt%. Most importantly, the HA filtration experiments revealed that the incorporation of ND and especially ND-PEG particles reduced membrane irreversible fouling, dramatically. Meanwhile, the analysis of the fouling mechanism based on Hermia's model revealed that cake formation is a prevailing mechanism for all membranes.

Keywords Nanodiamond · Polyethylene glycol · Cellulose acetate · Nanocomposite membrane · Anti-fouling

Introduction

Membrane technology is widely used for water treatment and has obtained more attention than any other separation process due to low energy consumption, easy scale-up, less or no use of chemicals and no harmful by-product formation [1]. Humic acid (HA), an important component of natural organic matters (NOMs), is derived from the decomposition of the plant and animal materials that are commonly found in surface and ground water and strictly affect the taste and color of water [2–4]. Therefore, the removal of NOMs is extremely important and has become a challenging subject of research in the current development of water purification technologies.

Cellulose acetate (CA) is one of the foremost among ultrafiltration (UF) polymer membranes. It has been widely used in separation processes, due to its high hydrophilicity, high biocompatibility, good desalting, non-toxic nature, performance high potential flux, and relatively low cost [4–6]. However, this membrane usually contains a dense skin layer and a low porous sub-layer, which result in an extremely low flux [7]. On the other hand, one of the serious problems arising during UF membrane filtration is membrane fouling by NOMs [8]. Membrane fouling can be classified as reversible fouling (which can be eliminated by physical cleaning) and irreversible fouling (which cannot be entirely counteracted by physical cleaning and typically requiring chemical

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