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# Effect of cellulose nanocrystals and carboxylated multiwalled carbon nanotubes on performance of polyethersulfone membrane for humic acid removal

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ABSTRACT

Persistent declines in flux due to membrane fouling result in decreased treated water production, higher energy consumption, and a frequent need for chemical cleaning. Carbon nanotubes-based membranes have shown remarkable separation capabilities in water treatment processes while being relatively resistant to biofouling. Cellulose-based membranes, on the other hand, have demonstrated outstanding biocompatibility and versatile surface chemistry. In the current study, a hybrid polyethersulfone (PES) membrane was synthesized by integrating with single cellulose nanocrystals (CNC), single carboxylated multiwalled carbon nanotubes (MWCNT), and a mixture of CNC and MWCNT utilizing the phase inversion method. This combination of nanomaterials was aimed at eliciting synergistic effects to enhance the overall membrane performance. The evaluation of the hybrid membranes encompassed an analysis of membrane structure, morphology, porosity, hydrophilicity, water flux, humic acid (HA) rejection, and the flux recovery ratio (FRR). The experimental outcomes unveiled notable changes in the morphology of the polymeric membrane when CNC and MWCNT were introduced into the PES membrane structure. All hybrid membranes displayed heightened hydrophilicity compared to the original pristine PES membrane. The PES/CNC0.3/CNT0.03 membrane demonstrated exceptional performance, with a remarkable HA rejection rate and FRR of 93.05% and 92.09%, respectively. This outstanding performance can be attributed to the synergistic combination of two separation mechanisms: electrostatic repulsion and size exclusion. The inclusion of MWCNTs into the hybrid membranes significantly reduced humic acid-induced membrane fouling due to improve surface hydrophilicity and decreased membrane roughness.

## 1. Introduction

Membrane technology has emerged as an effective physical separation method for water treatment. Ongoing research efforts have focused on improving existing membrane materials' performance, integrity, and environmental sustainability (Sadare et al., 2022). Polymer filtration membranes, particularly ultrafiltration, have been widely used for treating a variety of contaminated water sources due to their low energy requirements, ease of automation, and ability to produce high-quality treated water (Younas et al., 2018). However, fouling continues to be a significant obstacle restricting membrane technology's widespread and frequent use.

Natural organic matter (NOM) is the primary source of foulants in membrane filtration, leading to reversible and irreversible fouling. High concentrations of NOM can be hazardous to aquatic life and pose health risks to humans through direct exposure or bioaccumulation (Hakami et al., 2019; Jalanni et al., 2013). Humic acid (HA), a water-soluble high-molecular-weight material derived from the decomposition of animal, microbial, and plant wastes, is a major component of NOM and accounts for more than half of it (Nazri et al., 2021). HA is responsible for water's dark color and unpleasant taste and promoting bacterial growth. It is a complex component of molecules with different molecular

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