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Treatment of wastewater from oil palm industry in Malaysia using polyvinylidene fluoride-bentonite hollow fiber membranes via membrane distillation system

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ABSTRACT

Membrane distillation (MD) is gaining increasing recognition within membrane-based processes for palm oil mill effluent (POME) treatment. This study aims to alter the physicochemical characteristics of polyvinylidene fluoride (PVDF) membranes through the incorporation of bentonite (B) at varying weight concentrations (ranging from 0.25 wt% to 1.0 wt%). Characterization was conducted to evaluate changes in morphology, thermal stability, surface characteristics and wetting properties of the resulting membranes. The resulting membranes were also tested using direct contact membrane distillation (DCMD) with POME as the feed solution, aiming to generate high-purity water. Results indicated that the PVDF-0.3B and PVDF-0.5B membranes achieved the highest water vapor flux. The finger-like structure and macrovoids present in these membranes aid in minimizing mass resistance during vapor transport and enhancing permeate flux. All membranes demonstrated exceptional performance in removing contaminants, eliminating total dissolved solids (TDS) and achieving over 99% rejection of chemical oxygen demand (COD), nitrate nitrogen (NN), color, and turbidity from the feed solution. The permeate water analysis showed that the PVDF-0.3B membrane had superior removal efficiency and met the standards set by the local Department of Environment (DOE). The PVDF-0.3B membrane was chosen as the preferred option because of its consistent flux and high removal efficiency. This study demonstrated that incorporating bentonite into PVDF membranes significantly enhanced their properties and performance for POME treatment.

1. Introduction

Membrane distillation (MD) is a separation mechanism that is induced by thermal processes. Utilizing microporous membranes, MD exclusively permits the passage of vapor molecules (Mokhtar et al., 2015b; Muhamad et al., 2019; Wae Abdul Kadir et al., 2020). The method boasts several notable benefits, including reduced operational pressure, efficacy even with low mechanical resilience, straightforward modular scalability, absence of chemical additives, high rates of removing dissolved non-volatile components, and a diverse range of materials suitable for constructing membranes (Hubadillah et al., 2019; Ma et al., 2024; Ye et al., 2024). In MD applications, hydrophobic membranes are essential, with polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE), and polypropylene (PP) being commonly employed for membrane fabrication (Alsebaeai and Ahmad, 2020; Costa et al., 2023). Due to its robust mechanical properties, hydrophobic nature, ease of processing, chemical resilience, and thermal stability, PVDF membranes are extensively favored for membrane development (Cui et al., 2018).

In many applications, adding inorganic nanomaterials to polymeric matrices has demonstrated an enhancement in the physicochemical attributes and separation capabilities of membranes (Hosseini Hashemi

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