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Effects of temperature on a dynamic deposition layer of PDA on a ceramic hollow fiber

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Abstract

Oily wastewater is a contaminant that poses a serious threat to aquatic life and pollutes aquifers, and its treatment or reduction of pollutant concentrations to an acceptable level is considered a way to minimize its impact on the environment [3]. Traditional oil-water separation methods struggle to achieve effective results for the separation of wastewater with low oil concentrations (i.e., < 400 mg/L) [1], making membrane technologies an attractive alternative because of their high oil removal efficiency, compactness, and low energy cost. However, membrane fouling remains a common issue that compromises the permeability and cost-effectiveness of the membrane processes.

Efforts have been made to modify the surface of ceramic membranes to address their low fouling resistance to organic compounds [5]. Polydopamine (PDA) is hydrophilic and can strongly adhere to various materials, offering an interesting alternative for the surface modification of membranes to obtain better fouling resistance [2]. Dynamic deposition of PDA can produce a very thin layer on the membrane surface, and it has been used to develop membranes for different processes, such as micro and ultrafiltration [4,6]. To reduce fouling of ceramic membranes by oily wastewater, as well as to enhance cleaning efficiency of the membrane, the aim of this study was to investigate the dynamic deposition of polydopamine (PDA) as a protective layer on hollow fiber ceramic microfiltration membranes. The effect of the temperature of polymerization of PDA on the performance of the membrane was studied at 25 °C and 45 °C, and the prepared membranes were named CM-PDA25 and CM-PDA45, respectively. The antifouling performance of the membrane modified with the PDA layer was compared with that of a pristine ceramic membrane (CM).

Microporous hollow fibers were prepared by the wet spinning process from low-cost commercial alumina with a wide particle size distribution and solutions of poly(ether sulfone) and poly(vinyl pyrrolidone) in N-methylpyrrolidone. Thermal treatment was used to burn the polymers and sinter the alumina particles. The particle size distribution contributed to the formation of membranes with a uniform sponge-shaped morphology and a mean pore diameter of 0.8 µm, compatible with a microfiltration membrane. Investigation of the influence of the parameters involved in the formation of the membrane by phase inversion and control of the heat treatment conditions made it possible to obtain a porous support with high mechanical resistance and permeance (2,980 L/h.m2.bar).

A single-fiber crossflow module was prepared, and polydopamine (PDA) was deposited on the membrane surface. The membrane morphology before and after PDA deposition was observed using scanning electron microscopy (SEM). The performance of the membranes for oily water treatment was observed using an emulsion containing 100 mg/L of crude oil in water, and the permeation flux and rejection were determined. The effects of the PDA polymerization temperature on the membrane performance are shown in Figure 1. It should be noted that a higher reaction temperature reduces the membrane permeance and increases the oily phase rejection, which may be related to the formation of a thicker PDA layer that leads to a higher mass transfer resistance for oil and water permeation. At a reaction temperature of 45°C, the membrane permeance decreased to 660 L/h.m2.bar, but the rejection of the oily phase increased from 60% to 98%. To our knowledge, these results are promising and superior to those reported for the polymer and ceramic membranes used in oily wastewater treatment.

Another interesting characteristic of the PDA-modified membranes is shown in Figure 2, which shows a decrease in the normalized permeate flux of the pristine, CM-PDA25, and CM-PDA45 membranes. In the pristine membrane, the permeate flux reduction was greater than 80%, and the membranes modified with the PDA layer were lower, reaching approximately 40% for the CM-PDA45 membrane. This result can also be attributed to the increase of the thickness layer of the PDA-modified membranes, which reduces the oily phase adhesion to the membrane surface.

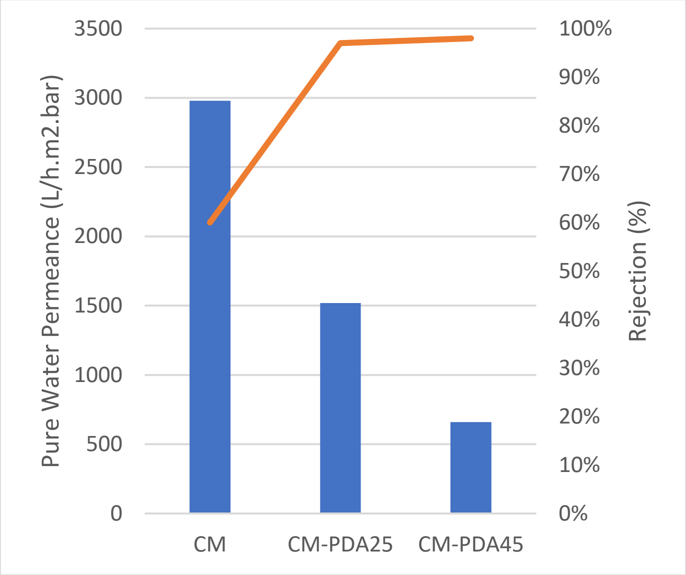

Figure 1 - Effect of PDA reaction temperature on the pure water permeance (blue bars) and oily phase rejection (orange line) of the ceramic membrane.

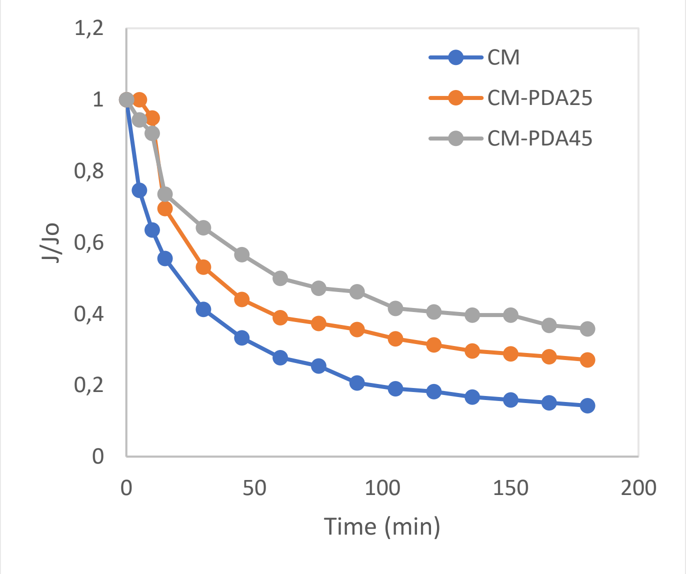

Figure 2 – Normalized flux decline for ceramic membrane (CM) and PDA modified membranes.

References

[1] Ahmad, T., Guria, C., & Mandal, A. (2020). A review of oily wastewater treatment using ultrafiltration membrane: A parametric study to enhance the membrane performance. J. of Water Proc. Eng., 36, 101289.

[2] Gao, N., & Xu, Z. K. (2019). Ceramic membranes with mussel-inspired and nanostructured coatings for water-in-oil emulsions separation. Sep. and Purif. Tech., 212, 737-746.

[3] Hussain, A., & Al-Yaari, M. (2021). Development of polymeric membranes for oil/water separation. Memb., 11(1), 42.

[4] Pan, Y., Wang, W., Wang, W., & Wang, T. (2015). Prediction of particle deposition and layer growth in the preparation of a dynamic membrane with cross-flow microfiltration. Rsc Advances, 5(108), 89015-89024.

[5] Wang, C., Wu, H., Yu, G., Zha, H., & Han, R. (2023). Fast preparation of a polydopamine/ceramic composite nanofiltration membrane with excellent permselectivity. RSC advances, 13(1), 615-623.

[6] Xiong, Y. S., Li, W., Lu, H. Q., Liao, C. Y., Yu, H. Q., & Li, K. (2022). Polydopamine-modified ceramic membrane for filtering brown sugar redissolved syrup: Characterisation, experiments, and advanced modelling. J. of Membr. Sci., 657, 120607.