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Low-Cost Ceramic Membranes from Fuller's Earth Clay and Sugarcane Bagasse Ash: Fabrication, Characterization, and Microfiltration Performance

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Abstract

This study introduces a sustainable methodology for fabricating cost-effective ceramic membranes through the amalgamation of two locally available and economical raw materials: fuller's earth clay (FEC) and sugarcane bagasse ash (SBA). Three membrane compositions were created through uniaxial dry-pressing and subsequently sintered at 850 °C: M1 (100% FEC), M2 (95% FEC+5% SBA), and M3 (90% FEC+10% SBA). The raw materials were characterized using XRD, XRF, SEM-EDX, FTIR, TG-DTA, and the particle size distribution (PSD). XRF showed that SiO2 (48.40%) and Al_2O_3 (15.50%) make up most of FEC. TG-DTA analysis showed that all volatile compounds are released below 850 °C, which confirms that the chosen sintering temperature is correct. The fabricated membranes were tested for their physical, mechanical, structural, and transport properties. As the SBA content increased, linear shrinkage decreased from 13.5% (M1) to 9.4% (M3), and porosity surged from 36.5% to 39.1%. After being immersed in strong acid (HCl, pH 1) and strong base (NaOH, pH 14) for a week, the membranes only lost 2.22-2.77% and 0.54-0.70% of their weight, indicating that the fabricated membranes can withstand harsh chemical environments. The three-point bending test showed membranes M1, M2, and M3 exhibited a strong mechanical strength of 36.6 MPa, 25.12 MPa, and 7.51 MPa, respectively. SEM imaging showed that the surfaces were very porous and granular, and FTIR and XRD tests showed that the silicate and aluminosilicate phases were still present after sintering. Dead-end filtration showed that the water flux increased linearly with pressure (0.35 to 1.72 bar), resulting in hydraulic permeabilities of 174.2, 460, and 571.8 L m^{-2} h^{-1} bar^{-1} for M1, M2, and M3, respectively. The calculated pore sizes of 0.365, 0.512, and 0.85 µm put all three membranes in the microfiltration range. Using an activity-based costing method, the total cost of production was about 53-54 \$/m^2, which is much lower than the cost of commercially available zirconia or alumina-based membranes (500-3000 \$/m^2). These results prove that FEC-SBA ceramic membranes are a promising, cost-effective, and environmentally friendly alternative for microfiltration applications. They also support the goals of the circular economy and UNSDG 12.

Keywords: fuller's earth clay, sugarcane bagasse ash, low-cost ceramic membranes, microfiltration, sustainability

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