Synthesis and Characterization of low-cost ceramic membranes: Application for wastewater Treatment

N. Malik[1*], V. K. Bulasara[2], S. Basu[3]

[1]School of Chemistry & Biochemistry, Thapar University, Patiala, India
[2]Department of Chemical Engineering, MANIT, Bhopal, India
[3]School of Chemistry & Biochemistry, Thapar University, Patiala, India

[*]Corresponding Author

ABSTRACT

In the present work, low-cost ceramic membranes are prepared by paste casting method using kaolin and fly ash along with other additives such as sodium metasilicate, boric acid and calcium carbonate. The effect of raw materials composition (i.e., kaolin–fly ash ratio, K:F) on the membrane properties (strength, porosity, pore size, permeability, etc) was studied. The raw materials mixture was subjected to TGA, and the prepared membranes were characterized by SEM, XRD, liquid permeation, mechanical strength, and chemical stability tests. The TGA of the mixture indicated no weight loss above the chosen sintering temperature of 900 °C. The SEM analysis indicated that the membranes were free of defects and had homogeneous surface structure with evenly distributed pores of similar sizes. The XRD analysis identified crystalline phases of different minerals that contributed for the strength. The membrane porosity was evaluated based on the gravimetric method. Addition of 15% $CaCO_3$ provided sufficient porosity to all membranes (25–46%). It increased with an increase in the kaolin content (K:F) owing to the dehydroxylation of kaolin to metakaolin during the sintering process. On the other hand, the pore size (estimated by liquid permeation test) decreased with the K:F ratio, because of the smaller particle size of kaolin in comparison with fly ash. A K/F ratio of 0:1 resulted in the largest average pore size (2.3 μm) and the ratio of 1:0 yielded the lowest pore size (0.73 μm). The chemical stability and mechanical strength increased with increase in the K/F ratio because of formation of mullite, anorthite, metakaolinite, quartz and nepheline phases as evidenced from XRD. All membranes showed superior stability in basic conditions (pH ~ 13) while the membranes prepared using K/F ≥ 1 had permissible weight loss (< 4%) in acidic conditions (pH ~ 1.5). Considering all the membrane properties and cost of raw materials, a K/F ratio of 2:1 was found to be optimum among all the prepared membranes. The suitability of this optimized membrane (K/F = 2) was also tested in the microfiltration of natural organic matter, and the membrane showed excellent filtration performance with a separation efficiency of more than 92%. Although, the permeate flux declined steadily with time, it was recovered by membrane regeneration. Fitting of different models to the flux data indicated the formation of a cake layer because of concentration polarisation at the membrane surface during dead-end filtration. The permeate quality at low transmembrane pressure (1.03 bar) was found to be acceptable for drinking.

Keywords: Wastewater treatment, humic acid, ceramic membrane, microfiltration.