Electricity-assisted Antifouling Ceramic Membrane Modified by Magnéli Titanium Sub-oxides for Environmental and Biological Applications

By

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Abstract

Membrane fouling is a fatal disadvantage hindering the application of membrane separation technology, which decreases permeate flux and shortens membrane service life. This research aims to solve this problem by combining membrane separation technology with external electricity through electrophoretic or electro-oxidation effect. The Magnéli titanium sub-oxide Ti₆O₁₉, with robust physical properties and high electrical conductivity, was employed to modify the Al₂O₃ ceramic membrane to make a novel composite material. The Ti₆O₁₉ phase was obtained by dip-coating a TiO₂ layer followed by chemical reduction at 1050°C in H₂ atmosphere. The fabricated Ti₆O₁₉ layer exhibited a conductivity of over 200 S cm⁻¹ with particle size of 200 - 300 nm, average pore diameter of 350 nm and contact angle of 0°. The antifouling performance of the prepared tubular Ti₆O₁₉/Al₂O₃ membrane was evaluated through a home-made cross-flow electricity-assisted membrane filtration (EAF) module where the prepared membrane element served as both the electrode(s) and the filtration media. Two types of electrode configurations were explored for the design of EAF module, namely membrane-wire and membrane-membrane electrode configurations. For the former configuration, electricity was connected between the inner Ti₆O₁₉ layer and a wire electrode while the inner and outer modified Ti₆O₁₉ layers served as electrodes for the latter. The filtration performance using the designed EAF module was first evaluated for the treatment of emulsified oily wastewater. The system was further examined using two other typical feed solutions that are known to foul easily, humic acid (HA) and whey proteins.

It was found out that the membrane-wire electrode configuration was more effective, especially when electrophoresis plays the major role in fouling control. Through the addition of an electric field to the EAF module for the treatment of 200 mg L⁻¹ emulsified oily wastewater at extremely low conductivity, 2.9 times higher average permeate flux was achieved at the electric field of 150 V cm⁻¹ within 1 h compared with that of uncoated Al₂O₃ membrane. The COD removal (original COD of 550 mg L⁻¹) also improved from 95.3 to 98.5% correspondingly. When the applied electric field was set at 100 V cm⁻¹ for the treatment of 6 and 12 mg L⁻¹ total organic carbon (TOC) of HA without additional electrolyte, a flux comparable to that of Milli-Q water filtration was obtained with HA rejections of 96.5 and 91.0%, TOC removals of 88.3 and 86.7% respectively, much higher than those of uncoated Al₂O₃ membrane (both smaller than 5%). During the EAF process of whey proteins, mainly α-lactalbumin (α-LA) and β-lactoglobulin (β-LG), it was observed that the protein rejections of α-LA and β-LG at the electric field of 50 V cm⁻¹ and transmembrane pressure of 200 mbar were 47.3 and 67.7% respectively, much higher than 4.3 and 6.2%, values obtained from filtration with uncoated Al₂O₃ membrane. When the EAF module was applied for the concentration process of whey proteins from 2000 to 350 ml at the above conditions, the concentrations of α-LA and β-LG in the retentate were about 2.2 times of those using uncoated Al₂O₃ membrane with the average flux also improved by 25%. Filtration time was therefore saved from 3.9 to 3.1 h correspondingly. Therefore, the designed EAF module with Ti₆O₁₉/Al₂O₃ membrane is multifunctional, showing promising prospect for the mitigation of membrane fouling as well as the improvement of product quality.

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- ALL ARE WELCOME -