HEMP MEMBRANES WITH ANIONIC FUNCTIONALIZATION FOR EFFICIENT REMOVAL OF CATIONIC POLLUTANTS

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Abstract

The primary aim of this study is to develop a membrane from treated waste hemp fibers using a dimethyl sulfoxide/tetra-n-butylammonium hydroxide (DMSO/TBAOH) solvent system and citric acid (CA) as an efficient adsorbent for the removal of cations and cationic dyes from water. The bio-renewable membrane (cHM) was prepared at the appropriate molar ratio of functional groups, which provided multiple functionalities for effective removal of cationic pollutants. The formed lignocellulosic cHM adsorbent was characterized in terms of its physicochemical, structural, and morphological properties through point of zero charge (pH_{PZC}), porosity, Scanning Electron Microscopy (SEM), and Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) measurements. Pore size was determined using image analysis and the dry-wet weight method. The effects of pH, initial concentration, temperature, and contact time on adsorption were studied in batch adsorption experiments. The membrane demonstrated high adsorption capacities for cationic pollutants, with values of 398.7 mg g^{-1} for Safranine O (SO), 370.60 mg g^{-1} for Methylene Blue (MB), and 445.4 mg g^{-1} for Crystal Violet (CV), following Langmuir model fitting at 25°C. The adsorption process was found to be endothermic, spontaneous, and efficient, highlighting the membrane's potential for water purification. The kinetic parameters of the adsorption process were fitted to both pseudo-first-order and pseudo-second-order models. The five adsorption-desorption cycles yielded effluent waters rich in desorbed pollutants. Photocatalytic degradation of the desorbed dyes using commercial TiO_2 as a catalyst, along with the chemical precipitation of cations into solid form, resulted in treated water that met current legislative standards. Biodegradability tests of the spent membrane confirmed its environmentally safe disposal after 85% degradation. This work demonstrates the application of green chemistry in transforming waste biomass into a high-performance adsorbent for wastewater treatment, offering an eco-friendly technology for water purification.

Keywords: *hemp fibers, cationic pollutants, sustainable technology, adsorption process, biodegradability*