DEVELOPMENT OF A NANOCELLULOSE-BASED FUNCTIONAL MATERIAL FOR WASTEWATER TREATMENT

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Industrial wastewater containing organic pollutants, dyes, nutrients, and suspended solids has become a major environmental concern worldwide. Conventional wastewater treatment methods and synthetic membranes often face limitations such as high cost, membrane fouling, and poor biodegradability. This study focused on developing a sustainable nanocomposite membrane (NM) for industrial wastewater treatment applications by incorporating cellulose nanocrystals (CNCs) extracted from agro-vegetable food waste into a chitosan–alginate matrix to fabricate an eco-friendly membrane. Cellulose was extracted from mixed agro-vegetable food waste through alkaline and bleaching treatments, followed by acid hydrolysis for CNC production. Chitosan was extracted from shrimp shell waste, and NM was fabricated using CNCs, chitosan, and commercially available alginate, with calcium chloride and citric acid employed as crosslinking agents. Characterization of NM was performed using FTIR, DLS, and SEM. The filtration performance of the membrane was evaluated using Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Total Dissolved Solids (TDS), nitrate, phosphate, pH, and colour intensity. The cellulose and CNC yields were 19.34% and 37.49%, respectively. FTIR identified characteristic functional groups of NM, while DLS showed particle sizes near 100 nm, confirming the nanoscale nature of CNCs. SEM observations before and after treatment demonstrated effective pollutant retention and good membrane performance. The CNC-based NM demonstrated superior pollutant removal efficiency compared with membrane control and sand filtration systems. The highest nitrate removal efficiency achieved was 86.68%, together with reductions in TDS (30.16%), EC (30.22%), COD (42.15%), Phosphate (47.11%), and colour intensity (72.94%), with statistical analysis indicating significant differences among filtration treatments ($p < 0.05$). The improved treatment performance was attributed to the synergistic interactions among CNCs, chitosan, and alginate, which enhanced membrane stability, porosity, adsorption capacity, and hydrophilicity. The developed membrane shows strong potential as a low-cost, biodegradable, and environmentally sustainable alternative for industrial wastewater treatment.

Keywords: agro-vegetable food waste, cellulose nanocrystals, industrial wastewater treatment, nanocomposite membrane, waste valorization