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Topic of Research: Study on Formulation, Characterization, and Economically Viable Application of Polymer Nanocomposites for the Treatment of Industrial Effluents

FINDINGS

The aims of this PhD work are to synthesize polymer nanocomposites (PNCs) and to understand their structural and functional properties. The performance of PNCs in the remediation of industrial effluents, prediction of the adsorption process by artificial intelligence, and the study of their economic viability have been carried out to understand the practical acceptance of the synthesized materials in real-world industrial applications.

The study has been carried out by synthesizing four types of PNCs using conducting polymers, biopolymers, nanofillers, and naturally derived-carbon dots. The characterization results revealed that PNCs have chemical and thermal stability after incorporating carbon dots over nanoparticles. The modification of nanoparticles with carbon dots showed uniform dispersion over the polymer matrix due to improved interfacial adhesion between nanoparticles and polymers. Due to the uniform distribution, the materials have shown enhanced adsorption performance towards dyes and increases regeneration ability. The synthesized composites can be reused several times in a continuous adsorption process except for PANI-FO which can be reused only twice. The outcomes of the reusability testing revealed that all the composites synthesized with CDs have strong repeatability and stability. The CD-based composites show good adsorption behaviour towards metal ions.

Furthermore, adsorption validation results provide valuable insights into the adsorption mechanism and the potential application of PNCs for wastewater treatment. The adsorption isotherm best fits the Langmuir model employing monolayer adsorption for PANI-FO and PANI-FOCD. Moreover, both composites aligned with pseudo-2nd-order model, which indicates that adsorption is chemisorption and boundary layer diffusion could be the rate-limiting step. FTIR results suggested that dye forms electrostatic attraction, hydrogen bonding, and π-π interaction with PANI-FO and PANI-FOCD composite. SA-FOCD and EDA-CH-TiO_2-CD fitted with Freundlich and pseudo-2nd-order model depicting multilayer adsorption and chemisorption process. The findings of the statistical physical model analysis showed that adsorption of MV was occurring by parallel and non-parallel orientation. FTIR results showed that dye forms electrostatic attraction, π-π interaction and hydrogen bonding with SA-FOCD composite, and EDA-CH- TiO_2-CD.

The ANN model demonstrated robust predictive performance, enhancing the accuracy of synthetic wastewater treatment predictions. The cost analysis of the synthesized materials has shown lower wastewater treatment cost due to higher performance in terms of effluents removal, higher number of regeneration cycles and lower regeneration cost.

Keywords: Polymer nanocomposite; wastewater; carbon dots; economic viability; artificial intelligence