Activated Carbon Decorated Polypyrrole–Chitosan and Zinc Oxide Bio-Composite Derived from Rice Husk and Shrimp Shell for Efficient Dye Removal and Antimicrobial Applications

Lubna S. Majgaonkar
G. N. Khalsa College, Matunga, Mumbai, India

Dr. Rupinder Kaur
Professor, G.N. Khalsa College, Matunga, Mumbai, India

Dr. Surajit Some
UGC Assistant Professor, Department of Specialty Chemicals Technology (ICT), Mumbai, India

Abstract

Shrimp shell and rice husk wastes were converted through a one pot synthesis to produce a sustainable multifunctional biocomposite (AC–CH–ZnO–PPy) for wastewater treatment. The Shrimp shell was demineralized and deacetylated under acidic–basic conditions to yield chitosan, while rice husk was carbonized and chemically activated in concentrated H2SO4 to form activated carbon; both were integrated in a single pot procedure to simplify processing and improve material homogeneity. The bio matrix underwent in situ oxidative polymerization of pyrrole using ferric chloride and subsequent precipitation of ZnO nanoparticles from ZnCl2 and NaOH, producing a porous conductive hybrid with enhanced surface functionality, mechanical stability, and increased active sites. The Comprehensive characterization by XRD, FTIR, TGA, SEM and TEM confirmed successful composite formation, crystalline ZnO incorporation, improved thermal stability, and increased surface area and porosity. Batch adsorption studies (pH 8, 1.5 g L^{-1} dose, 60 min contact time) demonstrated 96.8% removal of methylene blue and a maximum adsorption capacity of 142.5 mg g^{-1}. Adsorption fitted the Langmuir isotherm and pseudo second order kinetics, indicating monolayer chemisorption predominates on a heterogeneous surface with favourable affinity. Additionally, the composite exhibited notable antimicrobial activity attributed to the synergistic biocidal effects of ZnO nanoparticles and conductive polypyrrole, suggesting dual-function remediation potential. Overall, this eco-friendly, low cost, and scalable approach converts agricultural and seafood wastes into a high-performance material for dye contaminated wastewater remediation and related environmental and antimicrobial applications

Keywords

Activated carbon, Chitosan, Polypyrrole, Zinc oxide nanoparticles, Methylene blue, Adsorption.