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Title: Parametric optimizations of genotoxic dye sorption using zinc-activated rice straw-derived cellulose: a study aligned with circular economy goals (SDG 12)

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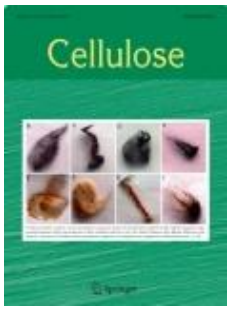
Abstract: Cellulose extraction from agro biomass is a viable solid waste management strategy that has the potential to be applied in various adsorption-based separation processes. Nevertheless, certain dyes, such as malachite green (MG), could be extremely difficult to eliminate adequately using untreated cellulose, hence raising concerns regarding the successful applications of cellulose. This study investigates the efficacy of ZnO-treated cellulose obtained from biomass pre-treatment, specifically focusing on enhancing the removal efficacy of MG. High-yield cellulose fiber was extracted from rice straw using a green solvent, which was further treated with ZnO and characterized to understand its structural and chemical properties. To study MG removal, equilibrium and kinetic studies were used to evaluate adsorption performance, and further advanced AI/ML-driven optimization improved the process efficiency. ZnO-treated cellulose dose of 0.4 g/L, MG concentration of 30 mg/L, pH 7, temperature at 30 °C, and stirring at 100 rpm yielded 98% MG removal efficiency. Using advanced computational approaches, the artificial neural network model (R^2 = 0.966) outperformed the response surface methodology model (R^2 = 0.91), demonstrating the potential for improved adsorption efficiency with ZnO-treated cellulose. This study underscores the use of ZnO-modified cellulose as a sustainable and circular solution for dye removal, in line with the United Nations Sustainable Development Goal (SDG) 12: Responsible Consumption and Production. By advancing eco-friendly wastewater treatment and valorizing agricultural biomass, the research promotes sustainability within an optimized, data-driven framework.



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