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Accurate data prediction by fuzzy inference model for adsorption of hazardous azo dyes by novel algal doped magnetic chitosan bionanocomposite

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A B S T R A C T

A bionanocomposite comprising of magnetic chitosan doped with algae isolated from native habitat was fabricated and utilized as an efficient adsorbent for the removal of hazardous azo dyes, namely, Direct Red 31 (DR31) and Direct Red 28 (DR28). The algal doped magnetic chitosan (Alg@mCS) was comprehensively characterized by Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Analysis (EDAX), Fourier Transform Infrared Spectroscopy (FTIR), X-ray diffraction analysis (XRD), and Brunauer-Emmett-Teller (BET). On the sorption of dyes, the influence of various process variables such as pH, adsorbent dosage, contact time, temperature, and initial dyes concentration were addressed. The adsorbent demonstrated maximal removal of DR31 and DR28 at pH 5 and 3, respectively. The maximum adsorption capacity of DR31 and DR28 was observed at Alg@mCS dose of 0.6 g L^{-1} and 7 g L^{-1} in 10 and 20 min, respectively. The Redlich Peterson isotherm model was shown to be appropriate for dye adsorption, indicating monolayer coverage of the dyes on the adsorbent surface ($R^2 > 0.99$). The adsorption process followed pseudo-second-order kinetics ($R^2 > 0.99$). Based on 320 experimental datasets from batch studies and interpolated data, adaptive neuro-fuzzy inference system (ANFIS) models were utilized to estimate dye elimination (percent). A number of parameters were calculated to validate the model's applicability. The Alg@mCS was proven to be a useful adsorbent for eliminating toxic and harmful azo dyes from aqueous solutions.

1. Introduction

In recent decades, synthetic dyes are the significant developers of water contamination due to their uncontrolled discharge into freshwater from a variety of fields such as textile fibers, printing, paper and pulp, food and beverage, cosmetics, leather, photography, and paint (Chatterjee et al., 2020). Currently, more than 10,000 varieties of synthetic dyes are promoted in the market with yearly output of 7×10^5 million tones out of which 5–10% of the dyestuffs are being squandered in the industrial effluents (Mashkoor et al., 2018). Direct red 31 (DR31) and Direct red 28 (DR28) are anionic water-soluble synthetic diazo (-N═N-) dyes that can trigger allergies and metabolized into benzidine, a carcinogenic product (Sharma et al., 2021) (Table 1). Due to their synthetic origin, complex structure, high thermal and photostability, it is very challenging to remove them, resulting in their long-term persistence in the environment. Inadequate treatment of these dyes can pose a number of health risks and severely contribute to climate change (Sinha et al., 2016). Hence, to protect water quality, proper treatment of these colors is required before they may be dumped into the natural environment.

For the eradication of these dyes from wastewater, various traditional procedures such as filtration, membrane technology, coagulation, dilution, photocatalytic degradation, and flotation have been developed (Bisaria et al., 2021; Dryaz et al., 2021). However, problems such as the complexity of the processes, production of toxic bi-products, limited removal efficiency, technical constraints, and high costs necessitate the development of novel wastewater treatment systems (Bisaria et al., 2022a). Biosorption is appealing alternative for current dye removal techniques from dye effluent (Abukhadra and Mohamed, 2019; Bisht et al., 2021). Chitosan is one such low-cost, abundant, renewable, and non-toxic carbohydrate biopolymer that has been used globally in a

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