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Engineered Nanosilica, Derived from Paddy Husk, for the Removal of Congo Red from Polluted Water: an Exploratory Study Using Mathematical Models and Adsorptive Experiments

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Abstract Synthetic dyes are highly endangering the environment and widely contributing to the water pollution. Congo red is also a synthetic dye with which many research works have been done to remove Congo red (CR) using adsorption technology. However, the adsorption capacity is still unsatisfactory. This work deeply investigated the CR removal utilizing engineered nanosilica, derived from paddy husk. The engineered nanosilica was produced from paddy husk at 700 °C for 6 h following the activation process using $CaCl_2$ at 500 °C for 30 min. Adsorptive experiments were done under a set of experimental conditions (dosage, 0.5 g/L; pH 6; rpm 150; holding time 24 h) to identify the best adsorption capacity. The engineered nanosilica with the highest adsorptive capacity (Q_e), among other adsorbents considered, (Q_e of raw paddy husk -18.48 mg/g; Q_e of biochar -25.42 mg/g; nanosilica - 48.53mg/g; and engineered nanosilica - 57.2 mg/g) was chosen for further studies: kinetics, thermodynamics, isotherm, and rate-limiting analysis, so as to understand the mechanism of adsorption of engineered nanosilica for CR removal. Additionally, to understand the functional properties of engineered nanosilica, the point of zero charge (pzc) and FTIR analysis were performed. Results revealed that the addition of the catalyst ($CaCl_2$) improved surface functional groups (oxygen containing functional groups) remarkably. Moreover, the removal of CR declined with raising temperature, representing endothermic adsorption process. Pseudo-second order kinetic model and Freundlich isotherm model were highly suitable for explaining the adsorptive mechanism of engineered nanosilica for CR removal. The first-time use of Boyd's external diffusion model clearly explained the strong involvement of chemisorption process in the removal of CR by the novel engineered nanosilica. All in all, the engineered nanosilica is an effective, environmentally benign, and affordable biomaterial to remove CR from polluted water.

Keywords Congo red · Engineered nanosilica · Isotherm analysis · Adsorptive mechanism · Catalyst · Paddy husk

1 Introduction

Water pollution is now the main problem in developing countries (Gwenzi et al., 2017). Accordingly, Sri Lanka has also promptly undergone quick industrialization, which lead to much more water contamination issues in the country (Ranaraja et al.,

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