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Preparation and characterization of magnetic $CaFe_2O_4$ nanoparticles for efficient adsorption of toxic Congo Red dye from aqueous solution: predictive modeling by artificial neural network

Akash Deb[a], M. Kanmani[a], Animesh Debnath[a], Kartick Lal Bhowmik[b], Biswajit Saha[b,*]

[a]*Department of Civil Engineering, National Institute of Technology Agartala, Jirania, West Tripura 799046, India, Tel. +918837309890; email: akashdeb341@gmail.com (A. Deb), Tel. +919677240499; email: kanmani.ar@gmail.com (M. Kanmani), Tel. +8575015404; email: debnathanimesh@gmail.com (A. Debnath)*

[b]*Department of Physics, National Institute of Technology Agartala, Jirania, West Tripura 799046, India, Tel. +919436569904; email: biswajit.physics@gmail.com (B. Saha), Tel. +9863585412; email: karticklalb@gmail.com (K.L. Bhowmik)*

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ABSTRACT

In this study, the performance and effectiveness of magnetic $CaFe_2O_4$ nanoparticles prepared by simple chemical route were evaluated for the adsorption of toxic azo dye Congo Red (CR) from aqua matrix. The prepared $CaFe_2O_4$ nanoparticles were characterized by X-ray diffraction, scanning electron microscopy, transmission electron microscopy, Fourier transform infrared spectroscopy, vibrating sample magnetometer, point of zero charge, and Brunauer–Emmett–Teller surface area measurements. Batch mode adsorption experiments were performed to study the effect of various experimental parameters namely solution pH (4.0–10.0), contact time (2–120 min), adsorbent dose (0.25–1.5 g/L), and initial CR dye concentration (20–150 mg/L) on the adsorption process. Maximum CR dye removal of 99.01% was achieved at solution pH 4.0 and maximum adsorption capacity of 241.16 mg/g was reported at optimum experimental condition. The adsorption equilibrium data strictly follows Langmuir isotherm model and adsorption kinetics was well described by pseudo-second-order model. A three layered artificial neural network (ANN) was applied for the accurate prediction of percentage of CR dye removal by the $CaFe_2O_4$ nanoparticles. The Levenberg–Marquardt backpropagation algorithm with "tansig" and "purelin" transfer function in hidden and output layer was used for model development. Optimal ANN architecture (4–9–1) shows high R^2 value (R^2: 0.995) and very low mean squared error value (0.00042866), confirming the accurate prediction ability of CR dye removal efficiency in this adsorption process.

Keywords: Congo Red; $CaFe_2O_4$ nanoparticles; Adsorption; Isotherm and kinetic studies; Artificial neural network modeling

* Corresponding author.