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Research article

Synthesis and characterization of Alg/Gel/n-HAP/MNPs porous nanocomposite adsorbent for efficient water conservancy and removal of methylene blue in aqueous environments: Kinetic modeling and artificial neural network predictions

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Abstract

In this study, a new porous nanocomposite adsorbent for water conservancy was synthesized using the freeze-drying technique to adsorb a cationic dye (Methylene Blue) in an aqueous environment. The nanocomposite adsorbent was synthesized using natural polymers, gelatin, and sodium alginate, and hydroxyapatite and magnetic iron oxide nanoparticles was incorporated into the polymer network to improve mechanical properties and increase the surface-to-volume ratio. To confirm the structure and morphology of the sample, Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscope (SEM) techniques were employed. In addition, the magnetic properties of the synthesis of MNPs and porous nanocomposite were determined using value stream mapping (VSM) and dynamic light scattering (DLS). The adsorption of Methylene Blue (MB) was studied as a function of effective physical and variable parameters, such as time, temperature, pH, and initial concentration. The synthesized porous nanocomposite adsorbent exhibited a high adsorption capacity of 473.2 $mg g^{-1}$ and followed pseudo-second-order kinetics. Additionally, the maximum adsorption capacity was observed at an initial concentration of 534.9 $mg g^{-1}$. The adsorbent was also sensitive to temperature changes and was well-described thermodynamically and isothermally by the Freundlich isotherm model. Two artificial neural networks (ANNs) were also developed to investigate the properties of the synthesized nanocomposites. In the first ANN, the properties of the nanocomposites, including pore size, porosity, compressive strength, and elastic modulus, were predicted based on the variations in the weight percentages of gelatin and hydroxyapatite. In the second ANN, the effects of changes in temperature and initial concentration on the adsorption of MB by the synthesized nanocomposite samples were predicted. The ANNs' predictions indicated that increasing the weight percentage of hydroxyapatite nanoparticles and gelatin enhances the physical, mechanical, and adsorption performance of the synthesized porous nanocomposites. The best results were achieved for the sample containing 40 wt % of gelatin and 30 wt % of hydroxyapatite nanoparticles. Furthermore, the ANN models demonstrated that increasing the temperature and initial concentration resulted in an increase in the amount of MB adsorbed.