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Potential Biopolymer Adsorbent Functionalized with Fe_3O_4 Nanoparticles for the Removal of Cr(VI) From Aqueous Solution

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Abstract

In the present study, an adsorbent with a synergistic effect was developed from chitosan (CS) and Fe_3O_4 nanoparticles (Fe_3O_4 Nps) to remove Cr(VI) from aqueous solutions. The Fe_3O_4 Nps were synthesized by co-precipitation and were characterized by TEM. The CS/NPs composites were prepared by electrospinning technique and analyzed by SEM, FT-IR, DSC, and TGA. In the batch system, the influence of Fe_3O_4 Nps content, pH, contact time, Cr(VI) initial concentration, adsorbent dosage, and the temperature was investigated; the Cr(VI) concentration was determined using a colorimetric method by UV–Vis spectroscopy. The Fe_3O_4 Nps presented a *quasi*-spherical shape and an average size of 18 nm, with a low particle distribution. The SEM analysis reveals the presence of highly porous, interconnected micrometric structures. The optimal adsorption conditions were 1% load of Fe_3O_4 Nps by weight of CS, pH 3, 25 °C, and equilibrium was reached at just 9 min. Besides, the adsorption is favored by increasing Cr(VI) initial concentration and adsorbent dosage. The studies of reaction kinetics and adsorption equilibrium showed that the experimental data were better fitted to the Pseudo-second-order and Langmuir isotherm models, establishing monolayer formation and chemisorption. The maximum adsorption capacity of CS/Fe_3O_4 Nps was 440.75 mg/g, which indicates a high affinity of the adsorbent for Cr(VI). Finally, a kinetic diffusion study established that intraparticle diffusion, and in particular surface diffusion, are important resistances in the transport of Cr(VI) from the liquid phase to the active site.

Keywords Chitosan · Fe_3O_4 nanoparticles · Cr (VI) removal · Metal adsorption

Introduction

Chromium is a pollutant commonly introduced in natural sources by the discharge of wastewater from industrial activities, such as those dedicated to the manufacture of paints, leather tanning, fertilizer production, among others 0. In aqueous systems, chromium exists primarily in two oxidation states: trivalent chromium Cr(III) and hexavalent chromium Cr(VI). Cr(III) is less toxic than its hexavalent form; and at trace level, it is an essential element for mammals [1]; it is relatively immobile but can be oxidized to Cr(VI) in aquatic environments [2, 3]. On the other hand, the hexavalent form of chromium is much more soluble and mobile in aqueous systems [4, 5]. The hexavalent chromium species occur mainly as anions in the form of dichromate and hydrogen chromate ($Cr_2O_7^{2-}$ and $HCrO_4^-$, respectively) in acid medium, and as chromate (CrO_4^{2-}) in alkaline medium [6]. These act as human carcinogens and mutagens [7]. In addition, they are toxic to many plants, aquatic animals, and bacteria [8, 9].

Several techniques, both conventional and advanced, are used in the industry to remove and/or reduce the Cr(VI) concentration of wastewaters, such as chemical precipitation (use of reducing agents before precipitation to reduce Cr(VI) to Cr(III)), ion exchange, solvent extraction, membrane separation, evaporation, electro-regulation, reverse osmosis, phytoextraction, ultrafiltration, and adsorption

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