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Adsorption and kinetic behavior of Cu(II) ions from aqueous solution on DMSA functionalized magnetic nanoparticles

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ABSTRACT

In this work, magnetic nanoparticles (MNPs) synthesized by the solvothermal method and functionalized by meso-2,3-dimercaptosuccinic acid (DMSA) by ligand-exchange protocol were used as nanoadsorbents to remove Cu(II) ions from aqueous solution. The magnetic nanoadsorbents were characterized by X-ray diffraction (XRD), transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR) and vibrating sample magnetometer (VSM). The functionalized MNPs were used for removal of Cu(II) by batch adsorption technique under different influencing parameters such as contact time, adsorbent dose, initial Cu(II) concentration, and pH. The adsorption behaviour of Cu(II) on MNP-DMSA follows Pseudo-first-order kinetic model. Removal efficiency was found to decrease from 98 to 64% by increasing the Cu(II) concentration in the solution from 50 to 300 ppm. The experimental data for the adsorption of Cu(II) were found to follow the Langmuir isotherm and the maximum adsorption capacity was 25.44 mg/g.

1. Introduction

Rapid industrial development and urbanization are responsible for the increasing levels of ground-water pollution and due to this; the quality of drinking water has reduced significantly [1]. In recent years, water streams are polluting due to the discharge of toxic heavy metals from industries such as fertilizer, mining, metal plating, textile industries etc. Heavy metals are not decomposable and can accumulate in living organisms [2,3]. This can lead to various disorders and diseases. The most alarming toxic heavy metals are copper (Cu), mercury (Hg), chromium (Cr), arsenic (As), lead (Pb), cadmium (Cd), and nickel (Ni) [1,4–7]. Therefore it is of utmost important to remove these toxic heavy metal ions from contaminated wastewater.

For the removal of toxic heavy metals from contaminated wastewater, various conventional methods are available. These methods include membrane filtration, microbial system, coagulation, electrochemical process, chemical precipitation, ion-exchange, adsorption, photocatalytic degradation etc. [8,9]. Among these methods, adsorption is the most effective option due to its ease of operation, low operating cost, high efficiency, and low fouling problems.

In last few decades, many types of adsorbents such as activated carbon [10], silica gel [11], zeolite [12], clay minerals [13], and magnetic nanoparticles (MNPs) [14] have been explored for heavy metal removal. Among these adsorbents, MNPs with high surface to volume ratio and good colloidal stability results in superior adsorption kinetics for various metal ions in aqueous solutions. Further unique magnetic properties of MNPs can be explored for easy and fast separation of nanoadsorbent from the aqueous solution. The combination of adsorption and magnetic separation holds the advantage due to operational flexibility, recovery of heavy metals, and reusability of adsorbent MNPs.

Several factors need to be considered to achieve efficient removal while using MNPs as an adsorbent. For colloidal stability and easy magnetic separation, nanoparticles should be superparamagnetic with higher magnetization [15]. To improve the heavy metal uptake capacity by MNPs, they need to be surface modified to provide specific functional groups or reaction sites that can be selective and specific for ions uptake. MNPs can be functionalized with some compounds, such as humic acid [4], meso-2,3-dimercaptosuccinic acid (DMSA) [16], (3-aminopropyl)triethoxysilane [17,18], and chitosan [19]. Different

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