Hindawi
Advances in Materials Science and Engineering
Volume 2017, Article ID 1210673, 13 pages
https://doi.org/10.1155/2017/1210673

*Research Article*

# Adsorption Equilibrium for Heavy Metal Divalent Ions ($Cu^{2+}$, $Zn^{2+}$, and $Cd^{2+}$) into Zirconium-Based Ferromagnetic Sorbent

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Received 22 December 2016; Revised 19 March 2017; Accepted 6 April 2017; Published 5 July 2017

Academic Editor: Peter Majewski



Zirconium-based ferromagnetic sorbent was fabricated by coprecipitation of $Fe^{2+}$/$Fe^{3+}$ salts in a zirconium solution and explored as a potential sorbent for removing the $Cu^{2+}$, $Zn^{2+}$, and $Cd^{2+}$ from aqueous solution. The sorbent could easily be separated from aqueous solution under the influence of external magnetic field due to the ferromagnetism property. A trimodal distribution was obtained for the sorbent with average particle size of 22.74 $\mu$m. The –OH functional groups played an important role for efficient removal of divalent ions. The surface of the sorbent was rough with abundant protuberance while the existence of divalent ions on the sorbent surface after the sorption process was demonstrated. Decontamination of the heavy metal ions was studied as a function of initial metal ions concentration and solution pH. Uptake of the heavy metal ions showed a pH-dependent profile with maximum sorption at around pH 5. The presence of the ferromagnetic sorbent in solution at different initial pH has shown a buffering effect. Equilibrium isotherms were analyzed using Langmuir, Freundlich, Dubinin-Radushkevich, and Temkin isotherm models. Adequacy of fit for the isotherm models based on evaluation of $R^2$ and ARE has revealed that heavy metal ions decontamination was fitted well with the Freundlich model.

## 1. Introduction

Heavy metals are natural constituents of earth's crust, but indiscriminate human activities have drastically transformed their geochemical cycles and biochemical balance [1]. At present, pollution of aquatic ecosystems by the heavy metals is a significant problem as the heavy metals constitute certain most hazardous substances that can bioaccumulate in environment and ecosystem. Toxic metal compounds on the earth not only reach the earth's waters (seas, lakes, ponds, and reservoirs), but also can contaminate underground water in trace amounts by leaking from the soil after rain and snow [2]. The toxic metal ions dissolved can ultimately reach top of food chain and therefore developed a risk factor for human health besides causing ecological damage [3].

The risk of heavy metal pollution to public health and wildlife has led to an enlarged interest in development of effective technologies for water purification. Adsorption process has evolved into one of the prominent methods for removing organic and inorganic pollutants in waterway systems [4]. This effective and economic process has been found superior to other techniques such as ion exchange and precipitation for treating aqueous effluents in terms of initial cost, simplicity of design, ease of operation, and insensitivity to toxic substances [5].

In recent years, the application of magnetic materials in solid phase extraction has received considerable attention by taking into account many advantages arising from the inherent characteristics of magnetic particles [6, 7]. The ferromagnetic sorbent can be easily recovered by magnetic separation technology and served as a satisfactory resolution for separation difficulty of ordinary powdered adsorbents. The ferromagnetic sorbent can simply be collected by an external magnetic field and such facile separation is essential to improving the operation efficiency. Additionally, the outstanding separation efficiency allows evacuation of the sorbent saturated with metal ions by means of magnetic captures, indicating a relatively simple technology without generation