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Adsorption of manganese in aqueous solution by steel slag

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Abstract

Batch experiments had been conducted to evaluate the ability of steel slag in removing manganese from aqueous solution. Several variables had been setup to evaluate the performance of steel slag in different experimental conditions. The variables include contact time, dosage, pH and initial concentration of manganese. The equilibrium contact time was achieved at 10 hours. 1 g of adsorbent dosage is considered enough to remove heavy metal from aqueous solution. The optimum pH for manganese adsorption onto steel slag was 6. Higher initial concentration leads to the decrease in percentage removal of Mn from solution, but increase in adsorption capacity. The Langmuir isotherm model fits well with data of Mn adsorption onto steel slag compared to Freundlich isotherm model. Steel slag is capable of removing high percentage of Mn from aqueous solution (>95%) in batch experiments, showing potential for real application on-site.

*Keywords:*Batch experiment; adsorption; steel slag; manganese; isotherm model

1. Introduction

Water from industrial activities has been a source of concern because of the contamination by toxic metals and other substances that require treatment before being discharged. Such treatment must be carried out using operations and processes that aim to reduce the contamination concentration to the level required by the environmental regulation or the authorities. Manganese is a common toxic metal that can be found in the effluents of many industries, as well as in mine waters, either in neutral or acidic mine drainage [1,2]. Generally, it is absorbed by the

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human body through oral or respiratory system and in high amounts, it can cause irreversible damages to the nervous system and other pathologies such as pneumonia, circulatory collapse, edema of the respiratory system, among others [3].

Current methods for the removal of heavy metals from water industry include precipitation, ion-exchange, reverse osmosis, solvent extraction, flocculation and membrane separation [4]. Oxidation and precipitation are the most common methods to remove Mn (II). Such method is based on the Mn (II) oxidation to its insoluble manganese dioxide [5]. Steel slag is a solid waste material which is by product of steel making industry. Globally, annual steel slag production produced is at fifty millions ton and dumping it off is gradually becoming a major environmental issue [6]. In this study, steel slag was chosen as a low cost adsorbent to be tested. The main objective of this study was to evaluate the ability of steel slag to remove manganese under different experimental conditions.

2. Materials and methods

2.1. Preparation and characterization of adsorbent

The steel slag was washed with distilled water to remove any debris and dried at 105°C for the period of 24 hours in an oven. The steel slag was then crushed and sieved into the sizes 1mm. The physical surface characteristics of steel slag (specific surface area and pore size) were determined using BET (Brunauer-Emmette-Teller) and BJH (Barrett-Joyner-Halenda) pore size distribution analysis. Scanning electron microscopy (SEM) along with EDX analyzer was used to obtain the morphological structure of steel slag and also the elemental composition of steel slag before and after adsorption.

2.2. Chemical and reagent preparations

All the chemicals and reagents used in this study were of analytical grade. Stock solution of Mn with concentration of 1000 mg/L was prepared by dissolving an appropriate amount of $MnSO_4.H_2O$ (manganese (II) sulfate-1-hydrate) with deionized water (Milipore Corp, USA). The stock solution was further diluted with deionized water to obtain desired concentration of Mn used in this study. 0.1 M NaOH and 0.1 M HNO_3 were used to adjust the desired pH throughout the experiments.

2.3. Batch Experiments

Several batch experiments with variation of variables were conducted to assess the performance of Mn adsorption onto steel slag. Orbital shaker with agitation speed of 200 rpm were used throughout the experiment to ensure homogenous mixing. The experiments were carried out at maintained temperature between 24-25°C. The effect of equilibrium contact time, size, dosage, pH and initial concentration were studied in the experiment.

2.4. Removal efficiency and adsorption capacity

Removal efficiency of adsorbent is calculated at time and also at equilibrium. The calculation of removal percentage (%) is calculated based on the equation (1) and (2):

$$\frac{C_o - C_e}{C_o} \times 100 \quad (1)$$

$$\frac{C_o - C_e}{C_o} \times 100 \quad (2)$$

While the amount of adsorbate adsorbed per unit mass of adsorbent, is calculated based on equation (3) and (4):

$$\frac{C_o - C_t}{m} \times V \quad (3)$$