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Removal of Pb(II) from aqueous solution using carbon derived from agricultural wastes

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Abstract

Batch adsorption studies were conducted to study the feasibility of using carbon derived from agro waste materials viz; pith, bagasse and saw dust for the purification of wastewater containing Pb(II). The effects of initial metal concentration, contact time, pH and adsorbent dose on the removal of Pb(II) were studied. Among the three adsorbents studied, carbon derived from pith showed better removal than the other adsorbents. Kinetics of removal of Pb(II) was studied using Lagergren rate plots and diffusion phenomena was analyzed using Weber and Morris intra particle diffusion plots. The applicability of the data was analyzed by Langmuir and Freundlich isotherm. Desorption of Pb(II) from the sorbed carbon was achieved by eluting with 0.1 M HNO_3. Carbon was retrieved by washing with 0.1 M $CaCl_2$ solution and reused.

Keywords: Adsorption; Pb(II); Pith; Saw dust; Bagasse; Langmuir isotherm; Freundlich isotherm

1. Introduction

Heavy metals are known to be detrimental to the living beings. They are important contaminants of liquid wastes discharged from a number of industries such as electroplating, dyes and dye intermediates, textiles, tanneries, oil refineries, electroplating, mining, smelters etc. The most common toxic metals found in industrial wastewater are Cr, Ni, Mn, Hg, Cd, Pb, Cu and Zn [1,2]. It has been observed that increased concentration of heavy metals in the aquatic environments can cause phyto toxicity, bio-concentration and bio-magnification by organisms. Pb(II) is a metal, which could be considered to be an environmental concern [3]. The problem of Pb(II) pollution due to use in Pb service pipes, particularly with soft water was the first recognized metal pollution. Other sources of Pb(II) pollution are battery industry, auto-exhaust, paints, etc. The maximum allowable concentration of Pb(II) in drinking water is 0.1 mg dm^{-3}. Major health effects due to Pb(II) poisoning are nervous and renal breakdown, weakness, headache, brain damage, convulsions behavioral disorders and constipation.

Removal of heavy metal bearing industrial effluents has become one of the primary challenges of wastewater treatment. The most widely used technique for the removal of dissolved heavy metals involves the process of neutralization and metal hydroxide precipitation. One of the shortcomings of this technique is the disposal of metal containing sludge arising out of the precipitation process. Hence there is a need for developing economic and eco-friendly methods for waste minimization and fine tuning of the wastewater. In recent years, the most promising alternative methods for removal of metal ions use the sorption by waste materials. Marshall and Champagne [4] evaluated the by products of soyabean and cottonseed hulls, rice straw and sugarcane bagasse as metal ion adsorbents in aqueous solutions. At a sub saturating concentration of metal ion (100 mg dm^{-3}), soya bean and cottonseed hulls adsorbed high levels (95.6–99.7%) of Cr(III), Co(III), Cu(II), Ni(II), and Zn(II). Vazquez et al. [5] have found that pretreated *Pinus pinaster* bark was an excellent ad-

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sorbent for removal of Zn(II), Cu(II) and Pb(II) from wastewater with efficiency comparable to commercially available adsorbents. Several studies [6–9] on metal removal by modified barks and agricultural residues have been reported.

Mass transfer is an important parameter in adsorption studies as it controls the cycle time of a fixed bed adsorption process. One of the most widely used sorption rate equation for the sorption of solute from liquid is the Lagergren first order rate equation [10]

$$\log(q_e - q) = \log q_e - \frac{K_{ad}}{2.303}t \tag{i}$$

where q_e and q are the amounts of Pb(II) adsorbed by unit weight of adsorbent at equilibrium and at time t.

The study of adsorption isotherms indicates the adsorption capacities of adsorbents at experimental conditions. Several authors have studied adsorption data using Langmuir and Freundlich adsorption isotherms [11–14].

1.1. Langmuir model

The Langmuir adsorption isotherm has been widely used in many adsorption processes. The basic assumption of Langmuir adsorption theory is that adsorption takes place at specific homogenous sites within the sorbent. It is also assumed that once a site is occupied by a metal ion no further sorption can occur. The driving force is the concentration in the solution and the bare area available for adsorption. Langmuir adsorption isotherm has been derived using all the above factors (Eq. (2)).

$$\frac{C_e}{q_e} = \frac{1}{q_{max}b} + \frac{C_e}{q_{max}} \tag{ii}$$

where C_e is the equilibrium concentration mg dm^{-3}, q_e is the amount adsorbed at equilibrium mg g^{-1}, q_{max} and b are Langmuir constants.

1.2. Freundlich model

The basic assumption of Freundlich isotherm is that if the concentration of the solute in the solution at equilibrium, C_e was raised to the power $1/n$, the amount of solute sorbed being q_e, then $C_e^{1/n} q_e$ was a constant at a given temperature. The Linear form of Freundlich model is expressed in the following equation

$$\log q_e = \log K + \frac{1}{n}\log C_e \tag{iii}$$

where C_e is the equilibrium concentration, mg dm^{-3}, q_e is the amount adsorbed at equilibrium mg g^{-1}, $1/n$ and K are Freundlich constants.

This study focuses the removal of Pb(II) by adsorption technique using carbon made from agricultural waste materials viz. pith saw dust and bagasse. The applicability of this technique was tested through laboratory scale experiments. The rate constants of the adsorption was studied using Lagergren first order rate equation. Adsorption capacities were studied in the light of Langmuir and Freundlich at experimental conditions.

2. Materials and methods

All chemicals used were of AR grade. Pith, saw dust and bagasse was obtained as waste from pulp, paper and sugar industry, respectively. The collected materials were washed twice with tap water and then with distilled water to remove sand and other materials. After sun drying, each material was taken in separate beakers. Activation was done by treating 1 part of the waste material with 1.8 parts by weight of concentrated sulphuric acid and held in an oven at 150 °C for 24 h. The carbonized materials obtained viz. Pith carbon (PC), saw dust carbon (SDC) and bagasse carbon (BC) were washed with distilled water several times to remove the free acid and dried at 105 °C. This material was used for adsorption experiments. The average particle size of the adsorbents were 0.5–0.8 mm. The pH, moisture content, ash content and bulk density were determined according to Standard Methods [15]. Surface area and porosity were determined using BET surface analyzer (Poresizer-micro metrics 9320). The physical properties of the adsorbents are presented in Table 1.

A stock solution of Pb(II) (10,000 ppm) was prepared by dissolving 4 g of $PbNO_3$ in 250 ml of double distilled water. Appropriate dilution of Pb(II) was made from the stock solution.

Adsorption experiments were performed at room temperature (27 ± 3 °C) using 100 ml metal solution and adding known quantity of the adsorbent. The reaction mixture was shaken in rotary shaker (agitation speed = 100 rpm). Optimized adsorption parameters were contact time, initial con-

Table 1
Physico-chemical characteristics of the investigated carbons

	Pith carbon (PC))	Saw dust carbon (SDC)	Bagasse carbon (BC)
Bulk density (g ml^{-1})	1.01	1.08	0.826
Moisture content (%)	6.8	6.23	8.1
Ash content (%)	6	1.8	1.3
Surface area (m^2 g^{-1})	380	226.5	312
Porosity (ml g^{-1})	0.61	0.41	0.35
pH (1% slurry)	5.6	5.8	5.6