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Original

Sorption of cyanide from aqueous medium by coffee husk: Response surface methodology

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Abstract

Cyanide is a very toxic compound that is released into the environment through industrial effluents; therefore, it needs to be removed prior to wastewater discharge. Adsorption is one of the most widely used treatment methods for removing contaminants from water and wastewater. In present research work response surface methodology was successfully employed for optimization and analysis of the adsorption process. Batch mode experiments were performed to determine the adsorption equilibrium of cyanide in aqueous solution. At optimum condition initial concentration (10 mg/l), contact time (1 h), adsorbent dose (1 g) and pH (8), 90.6% of cyanide adsorption was obtained. The factorial design and RSM analysis demonstrated that the experimental and the predicted values from the models were in agreement.

Keywords: Adsorption; Biomass; Pollutant; Wastewater; Toxic

1. Introduction

Organic pollutants have adverse effect on human health and environment. Cyanide is among one of them, and listed as toxic pollutants. It is a singly-charged anion containing unimolar amounts of carbon and nitrogen atoms triply-bounded together (Giraldo & Moreno-Piraján, 2010). Cyanide is a natural compound that is produced by living organisms including bacteria, fungi, algae and plants as part of a defence mechanism against predation (Mekuto, Jackson, & Ntwampe, 2013). However, these natural sources of cyanide are insignificant when compared to cyanide production by anthropogenic activities. Mostly mining, mineral processing, electroplating and plastics industries have significantly contribution to cyanide containing wastewater in the environment (US EPA, 1994). Uncomplexed cyanide, also called free cyanide, is the most toxic form of cyanide in wastewater because it is released as gaseous hydrogen (Osobamiro, 2012). The effects are so momentous to cause nerve damage and thyroid glands malfunctioning and established toxicity level (ASTM, 2006). As an environmentally protective measure, the Environmental Protection Agency (EPA) has placed rigorous limitations (0.1 mg/l) on the permitted cyanide concentrations levels in industrial wastewater effluent streams (Abbas, Abbas, & Ibrahim, 2014).

To treat the cyanide contained industrial effluent generally chemical oxidation techniques has been used (Botz, 2001; Dash, Gaur, & Balomajumder, 2009; Parga, Shukla, & Carrillo-Pedroza, 2003). Some other treatment technologies have been also introduced to treat the cyanide-containing wastewaters (Abbas et al., 2014; Hanela, Durana, & Jacobob, 2015; Palmer, Breton, Nunno, & Sulivan, 1988). However, these methods are expensive and hazardous chemicals are used as the reagents processes involving sorption have received greater attention and most widely accepted method for toxic contaminated wastewater (Agarwal, Balomajumder, & Thakur, 2013; Singh, Agarwal, & Balomajumder, 2016). The adsorption shows remarkable performance, including low investment cost, simplicity of design and operation, insensitivity to toxicants and effectiveness with low concentration of adsorbent (Mohammad, 2013). In literature

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some agricultural waste and by product has been used as absorbent to treat the industrial effluent (Anastopoulos & Kyzas, 2014; Prasad & Santhi, 2012; Singh et al., 2016). The use of biosorbents shows high removal due to primary building block of plant cell walls, lignocellulose contains cellulose, hemicellulose, lignin including little amount of protein, vitamins, lipids, combined with ash (Jorgensen, Kristensen, & Felby, 2007). Since, cyanide is a toxic compound well-known as a metabolic inhibitor, cyanide-containing effluents cannot be discharged without being subjected to treatment in response to increasing health and environmental awareness.

The main aim of this research work is to analyze the efficiency of coffee husk (adsorbent) for the removal of cyanide from synthetic aqueous solution in batch reactors. The adsorption is used for low concentrations of cyanide. The optimization of initial concentration, contact time, mass loading and pH were deliberated via response surface method experimental design. Prepared bioadsorbent has been characterized by scanning electron microscopy (SEM) and Fourier transformed infra red (FTIR).

2. Material and methods

2.1. Chemicals

All laboratory grade chemicals sodium cyanide, sodium hydroxide, hydrochloric acid were used without further treatment and supplied by Himedia Laboratories Pvt., Mumbai, India.

2.2. Sample

To avoid interference with other elements in wastewater, the experiments in this study were carried out using simulated synthetic aqueous solution of different cyanide ion concentrations. To prepare stock solution know amount weight of sodium cyanide dissolved in 1 L of millipore water (Q-H_2O, Millipore Corp. with resistivity of 18.2 MX-cm). The cyanide ion concentrations were measured using UV-spectrophotometer.

2.3. Preparation of adsorbent

The coffee husk was collected from processing unit. It was clean by washing with distilled water. Dilute sulfuric acid, 2% (v/v) and diluted sodium hydroxide, 2% (v/v) were used to pretreat 20 g of ground coffee husk biomass. Treatments were performed in triplicate at an autoclaved at 121 °C with 15 psi (103.4 kPa) for 90 min. Samples were neutralized with hot deionized water and dried at 60 °C overnight to completely remove moisture, then cooled to room temperature and stored in polybags until further use. The adsorbent was used in its original piece size. The chemical property of coffee husk is mention in Table 1.

Table 1
Characteristic of coffee husk.

S. no	Characteristics	Values
1	Specific gravity	0.71
2	Bulk density (kg/m^3)	395
3	Porosity (%)	79
4	Mean pore radius (A°)	5.4
5	Surface area (m^2/g)	0.39
6	Moisture content (%)	17.1
7	BET surface area (m^2/g)	910

2.4. Experimental design

A total of 30 experiments have been employed in this work to evaluate the individual and interactive effects of the four main independent parameters on the cyanide adsorption efficiency (Montgomery, 2001). Percentage adsorption has been taken as a response (Y) of the system, while four process parameters, namely, initial concentration 5–40 mg/l; pH: 2–10; contact time 1–3 h and adsorbent dose 0.5–5 g has been taken as input parameters. For statistical calculations, the levels for the four main variables X_1(IC), $X_2(t)$, X_3(g), X_4(pH) were coded as x_i according to the following relationship:

$$x_i = \frac{X_i - X_0}{\delta X} \quad (1)$$

where X_0 is value of X_i at the center point and δX presents the step change. The variables and levels of the design model are given in Table 2. The results of the Y (response) of adsorption were measured according to design matrix listed in Table 3. From experimental observations, it was assumed that the higher order interactions were small relative to the low order.

Experimental procedure batch experiments for optimization of process parameters were carried out in 250 mL round bottom flasks with working volume of 100 mL at 120 rpm in an incubator cum orbital shaker. A measure amount of adsorbate was added in measure initial concentrated of cyanide solution. The experiment carried out in room temperature (21 °C). The pH of solution was readjusted with 1 N NaOH or HCl during operation. The amount

Table 2
Factors and levels of the experimental design for adsorption.

Factors	Level (-2α)	Level ($-\alpha$)	Level (0)	Level ($-\alpha$)	Level ($+2\alpha$)
Inlet concentration (mg/l)	5	10	20	30	40
pH	2	4	7	8	10
Contact time (H)	1	1.5	2	2.5	3
Adsorbent dose (g)	0.5	1	3	4	5

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