Environmental Nanotechnology, Monitoring & Management 6 (2016) 176–183

Contents lists available at ScienceDirect

Environmental Nanotechnology, Monitoring & Management

journal homepage: www.elsevier.com/locate/enmm

Biosorption of heavy metals ions in real industrial wastewater using peanut husk as efficient and cost effective adsorbent

Ibrahim Abdelfattah[a,*], Adel A. Ismail[b,*], Fathy Al Sayed[c], Ali Almedolab[d], K.M. Aboelghait[a]

[a] Water Pollution Research Department, National Research Centre, P.O. Box 12622, 33 El-Bohouth Street, Dokki, Giza, Egypt
[b] Nanomaterials and Nanotechnology Department, Central Metallurgical Research and Development Institute (CMRDI), P.O. 87 Helwan, Cairo 11421, Egypt
[c] Chemistry Department, Faculty of Science, Menoufia University, Egypt
[d] General hospital of Sadat City, Menoufia, Egypt

ARTICLE INFO

Article history:
Received 16 July 2016
Received in revised form 16 October 2016
Accepted 27 October 2016

Keywords:
Bio-sorption
Removal
Heavy metals
Wastewater
Peanut husk

ABSTRACT

In this research, the practical feasibility of using a low-cost adsorbent, peanut husk powder (PHP), for the removal of different heavy metals ions, Pb^{2+}, Mn^{2+}, Cd^{2+}, Ni^{2+} and Co^{2+} from wastewater has been tested and the goal was achieved. The evaluation of PHP ability for bio-sorption of highly concentrated heavy metal ions (100 mg/L) from real industrial wastewater has been performed. The batch treatment process was employed to obtain the optimum parameters conditions such as bio-sorbent dose, pH values, shaking time and metal ions concentrations. The optimal conditions for the removal of metal ions using PHP were approximate pH value of 6, 5 g/L adsorbent dose, and 20 mg/L metals ions concentration, and 3 h shaking time. Thus, it was possible to obtain the highest removal efficiency with the following order $Pb^{2+} > Cd^{2+} > Mn^{2+} > Ni^{2+} > Co^{2+}$. Both adsorption parameters of Langmuir and Freundlich isotherms were calculated, and better-fitted experimental data to the Langmuir equation were obtained. PHP was employed to treat a metal finishing for processing industrial wastewater, and indicated the removal efficiency of Pb^{2+}, Fe^{3+}, Cr^{3+}, CN^{-}, Cu^{2+}, Cd^{2+}, Mn^{2+}, Zn^{2+}, Co^{2+} and Ni^{2+} ions of 100%, 95%, 56%, 51%, 45%, 41%, 38%, 30% and 24%, respectively.

1. Introduction

Wastewater remediation is considered to be one of the main approaches for water recycling that provides the deficiency of water in different regions in our daily life. To-date, only 10% of the produced wastewater is remediated and the residual wastewater is released into water resources such as rivers, seas and diffused into groundwater (Al-Zoubi et al., 2015). Heavy metals are considered to be the main contaminants in wastewater especially at high concentrations causing health problems in human beings and raising serious environmental issues (Chowdhury et al., 2016). They possess a specific gravity greater than 5.0 and having atomic weights between 63.5 and 200.6 (Fu and Wang, 2011). These metal ions have toxicity potential, and might cause carcinogenicity in the living organisms. The rapid development of industries leads to the production of huge amount of toxic heavy metals ions. They are indirectly or directly discharged into the water resources especially in developing countries. As a result of their non biodegradability feature and its tendency to accumulate in living organisms, treatment of industrial wastewaters is a particular concern for removing toxic heavy metals such as Pb(II), Cd(II), Ni(II), Co(II), Mn(II). . ..etc. at high and low level concentrations (Fu and Wang, 2011). There are several techniques employed for removing heavy metal ions such as chemical precipitation (Huisman et al., 2006; Alvarez et al., 2007), ion exchange (Alyüz and Veli, 2009; Abo-Farha et al., 2009; Zewail and Yousef, 2015), adsorption (Ismail et al., 2010, 2008; Mohamed et al., 2009), membrane filtration (Fu and Wang, 2011; Rether and Schuster, 2003; Gunatilake, 2015), coagulation and flocculation (Johnson et al., 2008; Amuda et al., 2006; Pang et al., 2009), electrochemical treatment (Hunsom et al., 2005; Chen et al., 2013), microorganism (Javanbakht et al., 2014; Ozdemira et al., 2009; Xiong et al., 2008). Unfortunately, all the above techniques have drawbacks including cost and sludge problems and/or maintenance problems. Bio-sorption of heavy metal ions is the removal of dissolved metal ions from water by certain types of biomass that has an ability to bind and concentrate metals ions. Bio-sorption is a cost effective and regenerative metal recovery technology for purifica-

* Corresponding authors.
E-mail addresses: iabdelhafiz@yahoo.com (I. Abdelfattah), adelali141@yahoo.com, aismail@cmrdi.sci.eg (A.A. Ismail).

http://dx.doi.org/10.1016/j.enmm.2016.10.007
2215-1532/

Table 1
Biosorption capacities of different biosorbents for removal of heavy metals ions.

Metal ions	Biosorbent	Maximum Adsorption (mg/g)	Reference
Ni^{2+}	Corn cob	12	Abdelfattah et al. (2016)
	Maize cob	18.4	Muthusamy et al. (2012)
	Saw dust	35	Adie et al. (2012)
	Maize cob	10	Adie et al. (2012)
	Corn cob powder	14.6	Arunkumar et al. (2014)
Pb^{2+}	Corn cob	32.4	Abdelfattah et al. (2016)
	Sawdust	15.9	Bulut and Tez (2007)
	Myriophyllum spicatum	55.1	Yan et al. (2010)
	Lichen (*Cladonia furcata*)	12.3	Sari et al. (2007)
	Macro-fungus (*Amanita rubescens*)	38.4	Sari et al. (2009)
	Saccharomyces cerevisiae yeast	72.5	Amirnia (2015)
Mn^{2+}	Corn cob	12	Abdelfattah et al. (2016)
	Leaves of dump palm	3	Jonathan et al. (2011)
	Plant biomass	7	Dubey et al. (2014)
	Maize stalk	5.5	El-Sayed et al. (2011)
Cd^{2+}	Corn cob	24	Abdelfattah et al. (2016)
	Zea maize waste	25	Jamil and Munwar (2009)
	Maize cob	20	Ibrahim (2013)
	Saw dust	5.2	Ibrahim (2013)
	Macro-fungus (*Amanita rubescens*)	32.5	Sari et al. (2009)
Co^{2+}	Corn cob	3.2	Abdelfattah et al. (2016)
	Pine saw dust	56	Musapatika et al. (2012)
	lemon peel	22	Bhatnagar et al. (2010)
	Amaranthus hybridus	19.5	Egila et al. (2010)

Table 2
Removal and Adsorption capacity (mg/g) of heavy metal ions by PHP as adsorbent.

No.	Metal ions	Removal (%)	Adsorption capacity (mg/g)
1	Pb^{+2}	(25–99)	(19.7–49.4)
2	Cd^{+2}	(23–62)	(12.3–46)
3	Co^{+2}	(3–30)	(6.1–25)
4	Mn^{+2}	(9–44)	(8.8–18)
5	Ni^{+2}	(10–39)	(7.9–20)

tion of wastewater from heavy metal ions (Abdelfattah et al., 2016). There are significant contributions of various research groups on removing heavy metals ions through the bio-sorption adsorbents and technologies as summarized in Table 1.

In the current contribution, we focused on the practical feasibility of using a low-cost adsorbent, peanut husk powder (PHP) for removing various heavy metals ions, Pb(II), Mn(II), Cd(II), Ni(II) and Co(II) from contaminated model and real wastewaters. In addition to studying the reaction kinetics, the goals of determining the optimum conditions to adsorb metal ions and obtaining the highest adsorption efficiency are achieved.

2. Materials and methods

2.1. Chemical and reagents

$Pb(NO_3)_2$, $CdCl_2$, $CoCl_2{\cdot}6H_2O$, $MnSO_4{\cdot}H_2O$, $NiCl_2{\cdot}6H_2O$, HCl and NaOH were purchased from Sigma-Aldrich and used as received without further purification. Freshly prepared model solutions of $Pb(NO_3)_2$, $CdCl_2$, $CoCl_2{\cdot}6H_2O$, $MnSO_4{\cdot}H_2O$ and $NiCl_2{\cdot}6H_2O$, with desired concentration were used as a source of heavy metal ions (adsorbate). Real sample of industrial wastewater was collected from a metal industry at Sadat industrial city and it was chemically characterized. pH values of the collected samples were adjusted for desired value via HCl (1 M) and NaOH (1 M).

2.2. Preparation of the bio-sorbent

Peanut husk was collected from a farm in Delta land, Menoufia, Egypt, washed thoroughly to remove dust using tap water, followed by deionized water, dried in an oven at 80 °C for 12 h, grinded using a laboratory mill, sieved, then washed with deionized water followed by washed with both diluted HCl and NaOH, then washed with by deionized water, and finally dried at 80 °C for 24 h.

2.3. Equipment

For shaking the suspension solution, Lab shaker, Wiseshake, SHO-2D, South Korea was utilized. pH-meter, WTW-inolab, Germany, was used for adjustment of pH values of the suspension solutions. The concentrations of heavy metal ions were determined using atomic absorption spectrometer Varian Spectr-AA (220), USA. PHP images were taken by scanning Electron microscope (SEM) images at different magnifications using Quanta-250 FEG, USA. FTIR absorption spectra of the PHP were recorded for the 350–4000 cm^{-1} range using Jasco-FTIR-Spectroscopy, Japan.

2.4. Methodology

For bio-sorption experiments, freshly prepared model solutions of Pb^{+2}, Cd^{+2}, Co^{+2}, Mn^{+2} and Ni^{+2} ions with known initial concentration and real industrial wastewater were employed. pH values for all prepared suspension solution were adjusted before conducting the experiments. Different bio-sorbent doses were added to 100 mL of prepared solution or to a real wastewater sample. The mixtures were shaken using lab shaker with speed 250 rpm for 0.5–6 h. The bio-sorbents were separated by filtration through, Whatman qualitative No. 4, filter paper. The concentration of residual heavy metal ions was determined using the atomic absorption spectrometer. All measured parameters of raw and treated wastewaters have been analyzed according to procedures given in The American Standard Methods (APHA, 2012). The treatment of real wastewater unit, which could be used in removal of heavy metals from real industrial wastewater, is shown in Scheme 1.