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Research Paper

Adsorption of Metal (Cd) from Wastewater by Plant Material (*Crotalaria burhia*)

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Abstract: *Cadmium is a highly toxic inorganic pollutant whose emission sources are widely diffused, giving rise to a large scale environmental pollution. Cadmium is one of the most toxic metals even in low concentrations. It is naturally produced in the environment and is a major contaminant. Cadmium (Cd) toxicity causes disorders such as heart disease, cancer and diabetes. The major objective of this paper was to investigate the removal of Cadmium (II) from wastewater using activated carbon prepared from leaves of Crotalaria burhia(AC-CB) an unconventional adsorbent. The dried leaves of Crotalaria burhia plant were used at different adsorbent/metal ion ratios. The influence of pH, contact time, metal concentration, and adsorbent loading weight on the removal process was investigated. Batch adsorption studies were carried out at room temperature. Removal efficiency increased with an increase in contact time before equilibrium is reached. The adsorption data fit well with the Langmuir and Freundlich isotherm models. This research focuses on understanding adsorption process and developing a cost effective technology for treatment of heavy metals-contaminated industrial wastewater. Comprehensive characterization of parameters indicates Crotalaria burhia to be a good material for adsorption of Cd (II) to treat wastewaters containing low concentration of the metal.*

Keywords: Wastewater, Crotalaria burhia, Adsorption isotherms, activated carbon.

Introduction

Cadmium is a highly toxic inorganic pollutant whose emission sources are widely diffused, giving rise to a large scale environmental pollution. For these reasons, environmental regulations define severe limitations on the maximum cadmium concentration in natural water bodies as well as on the maximum allowed concentration for wastewater discharge.

Cadmium is one of the most toxic metals even in low concentrations. It is naturally produced in the environment and is a major contaminant. Cadmium (Cd) toxicity causes disorders such as heart disease, cancer and diabetes. Cadmium poisoning may also result in lung cancer, anemia, skin, pulmonary edema, bone diseases, brain damage and trachea-bronchitis. Cadmium accumulates in bone, liver and kidney and is even more poisonous than mercury. Taking in any considerable amount of Cd leads to instantaneous intoxication and damage to the liver and the kidney. Cadmium is mainly formed when waste streams are discharged from metallurgical alloying, ceramics, metal plating and sewage sludge.

Material and Methods

Preparation of activated carbon from Crotalaria burhia (AC-CB)

The complete plant Crotalaria burhia was obtained locally. It was cut into small pieces. The small pieces was treated with sulphuric acid (2% v/v) in 1:1 ratio and was kept in an oven at 150°C for 24 hours. It was filtered and washed with distilled water repeatedly to remove sulphuric acid (washings tested with two drops of barium chloride solution) and finally dried. Chemical activation using sulphuric acid produces a high surface area and high degree of microporosity.

The adsorbent was sieved to 40-60 mesh size and heated at 110°C for 2 hours. This material was used as an adsorbent to study adsorption of metal ions at different pH.

Preparation of stock solution(Synthetic wastewater)

A stock solution of cadmium (2mg/ml) was prepared by dissolving Cd $(NO_3)_2.4H_2O$ in 0.1M HNO_3.The solution was standardized complexometrically with EDTA (disodium salt) using Xylenol orange indicator.

Adsorption studies

Batch adsorption studies were carried out to study the effect of pH (3, 4, 5, 6, 7 and 8), contact time (30-135 min), adsorbent dose (3-18 g/l) and initial metal ion concentration (60-150 mg/l) at room temperature using stopper bottles. The initial pH of solution was adjusted by using 0.1 M sodium hydroxide and /or 0.1 M nitric acid, without changing the volume of the sample. After agitating the sample for the required contact time, the contents were centrifuged and filtered through whatman No. 41 filter paper and unreacted Cadmium in the filtrate was analyzed .

The removal efficiency (E) of adsorbent was defined as:

$$E(\%) = \frac{(Co - Ce)}{Co} \times 100$$

Where Co and Ce is the initial and equilibrium concentration of metal ion solution (mg/l), respectively.

Adsorption Isotherm Models For Cd (II)

Freundlich isotherm

It has the general form of

$$\frac{X}{m} \, or \, q_e = K_f \, Ce1/n$$

The linearised Freundlich adsorption isotherm, which is of the form

$$\log q_e = \log K_f + \frac{1}{n} \log Ce$$

where:

qe = the amount of the adsorbate adsorbed per unit mass of adsorbent (mg adsorbate/g adsorbent)

X = the amount of the adsorbate

m = mass of adsorbent used (g)

Kf = adsorption capacity

n = adsorption intensity (the empirical constants)

Ce = equilibrium concentration of adsorbate (mg/L)

Linear plots of log qe(x/m) v/s log Ce at different adsorbent doses are applied to confirm the applicability of Freundlich models.

Langmuir isotherm:

$$\frac{Ce}{q_e} = \frac{1}{Qmb} + \frac{Ce}{Qm}$$

Qm and b is Langmuir constants related to adsorption capacity (maximum specific uptake corresponding to the site saturation) and energy (intensity) of adsorption (l of adsorbent /mg of adsorbate) respectively. The essential characteristics of the Langmuir Isotherm can be expressed in terms of a dimensionless constant, Separation factor or equilibrium parameter RL that defined as

$$RL = \frac{1}{(1 + b\,Co)}$$

Where Co (mg/1) is the initial concentration of the metal. Values of dimensionless equilibrium parameter RL show the adsorption to be favorable (0< RL<1).

Results and Discussion

The data obtained during the adsorption studies made here to evaluate the effect of contact time, pH of solution, adsorbent doses and isotherms on the removal of Cadmium from the synthetic wastewater have been analyzed and discussed under the following head.

Effect of contact time

In adsorption system, the contact time play a vital role irrespective of the other experimental parameters. Figure:1 depicts that there was an appreciable increase in percent removal of cadmium up to105 minutes and thereafter further increase in contact time the increase in removal was very small. Thus the effective contact time is taken as105 minute.

Effect of pH

The removal of metal ions from solution by adsorption is highly dependent on the pH of the solution. It was found that 73.5% and 68.3% removal of Cd (II) achieved at pH 6 and 7 respectively. Thus the optimum adsorption pH for Cd (II) is 6. (Figure 2) Due to strong adsorption of hydrogen ions from the solution and hydroxyl ions, the adsorption of other ions is strongly influenced.

Effect of adsorbent dose

The effect of adsorbent dose on percent removal of cadmium is shown in figure 3. Adsorbent dose was varied (3,6,9,12,15,18g/L) and performing the adsorption studies at pH 6. The present study indicated that the amount of Cd (II) adsorbed on AC-CB increase with increase in the AC-CB dose up to 15 g/l and thereafter further increase in dose the increase in removal was very small. Thus the optimal dose is 15g/l.

Adsorption Isotherms

Langmuir and Freundlich isotherms for Cd (II) by AC-CB were found to be linear showing the applicability of the isotherms.

Table 1: The values of Langmuir and Freundlich constants

Dose (g/L)	Langmuir constants				Freundlich Constants			
	Qm	b	R_L	R^2	KF	1/n	n	R^2
3	38.9105	0.01389	0.5454	0.9945	1.5674	0.5882	1.7001	0.9984
6	21.1416	0.0167	0.4995	0.9914	1.7298	0.5883	1.69981	0.9808
9	16.0514	0.01634	0.5049	0.9914	1.4504	0.5963	1.67701	0.9993
12	12.9199	0.01834	0.4761	0.9825	1.6618	0.5927	1.68719	0.9982
15	10.2041	0.02473	0.4026	0.9771	1.5471	0.5535	1.80668	0.9929
18	7.91139	0.02977	0.3589	0.9662	1.5472	0.5065	1.97433	0.9934

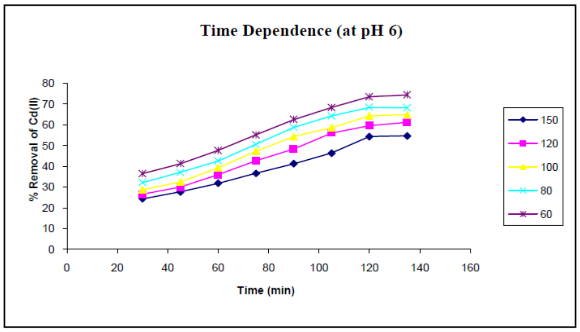

Figure 1: Effect of contact time on removal of Cd (II) at different concentration by AC-CB at pH 6

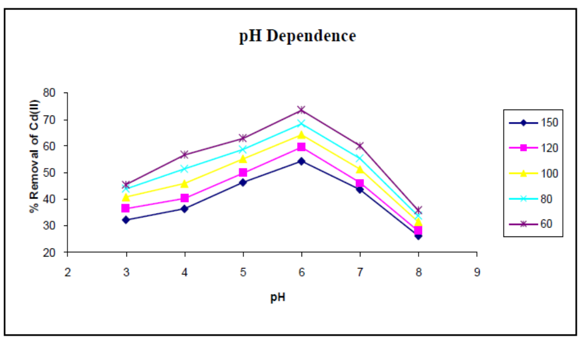

Figure 2: Effect of pH on removal of Cd (II) at different concentrations by AC-CB at constant contact time 105 min

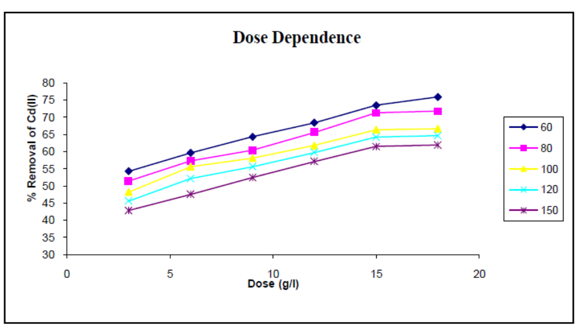

Figure 3: Effect of AC-CB dose on percent removal of Cd (II) at equilibrium contact time 105 min. and effective at pH 6

The values of Langmuir and Freundlich constants calculated from the graph are summarized in table: 1

for Cd (II) by AC-CB. Value of n for Cd (II) was 1.5760 by AC-CB at effective dose and contact time, indicates good adsorption potential of the adsorbent.

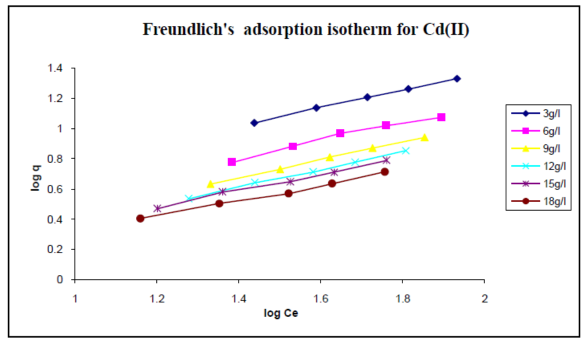

Figure 4: Freundlich Isotherm plot for Cd (II) adsorption by AC-CB at optimum conditions

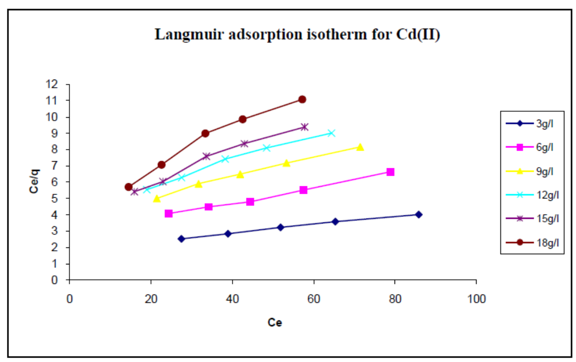

Figure 5: Langmuir Isotherm plot for Cd (II) adsorption by AC-CB at optimum conditions

Values of R^2 show the adsorption to be more favorable. A value of R^2 was 0.9904 for 60ppm Cd (II) solution by AC-CB.

Conclusion

This study indicates that AC-CB has rapid adsorption rate and good adsorption capacity for Cd (II). Maximum adsorption of cadmium 73.5 occurred at pH 6. The adsorption of metal ion on AC-CB reached equilibrium in 105min. and initial concentration 60 ppm. The Freundlich isotherms is followed better than the Langmuir .Since Crotalaria burhia plant are highly abundant and can be easily synthesized at relatively low cost, the adsorbent could be applied for the removal of cadmium from wastewaters.

References

1. Daga K., Adsorption of color from textile wastewater using crotalaria burnia, PMIP, 2004-ROURKELA(ORISSA), 205-209 **(2004)**

2. Langmuir I.J., The Adsorption of Gases on Plane Surfaces of Glass, Mica and Platinum, *J. Amer. Chem. Society*, **40(9)**, 1361-1403 **(1918)**

3. Freundlich H., 1926 Colloid Capillary Chemistry(London; Methuen)

4. Ulmanu M., Marañón E., Fernández Y., Castrillón L., Anger I., Dumitriu D., Removal of copper and cadmium ions from diluted aqueous solutions by low cost and waste material adsorbents, *Water Air Soil. Pollut*., **142(1-4)**, 357-73 **(2003)**

5. Kazemipour M., Ansari M., Tajrobehkar S., Majdzadeh M., Kermani H.R., Removal of lead, cadmium, zinc, and copper from industrial wastewater by carbon developed from walnut, hazelnut, almond, pistachio shell, and apricot stone, *Journal of Hazardous Materials,***150(2)**, 322-7 **(2008)**

6. Madhava Rao M., Ramesh A., Purna Chandra Rao G., Seshaiah K., Removal of copper and cadmium from the aqueous solutions by activated carbon derived from Ceiba pentandra hulls, *Journal of Hazardous Materials*, 129(1-3), 123-9 **(2006)**

7. Bohli T., Villaescusa I., Ouederni A., Comparative study of bivalent cationic metals adsorption Pb (II), Cd (II), Ni (II) and Cu (II) on olive stones chemically activated carbon, *J. Chem. Eng. Process. Technol*., 4(4), 1-7 **(2013)**

8. Vaishnav V., Daga K., Lal M., Adsorption of Metal (Cd) from Synthetic Wastewater by Plant Material, *Int. J. Res. Chem. Environ.*, **3(2)**, 148-154 **(2013)**

9. El-Eswed B., Alshaaer M., Yousef R.I., Hamadneh I., Khalili F., Adsorption of Cu(II), Ni(II), Zn(II), Cd(II) and Pb(II) onto Kaolin/Zeolite Based- Geopolymers, *Advances in Materials Physics and Chemistry*, **2**, 119-125**(2012)**

10. Módenes A.N., Espinoza-Quiñones F.R., Borba C.E., Trigueros D.E.G., Lavarda F. L., Abugderah M.M., Kroumov A.D., Adsorption of Zn(II) and Cd(II) ions in batch system by using the *Eichhornia crassipes*, *Water Sci. Technol*., **64(9)**, 1857-63 **(2011)**

11. Hatairat S., Orn-Anong A., Wimol N., Ponlayuth S., and Sorapong J., Isotherm, Kinetic and Thermodynamic Studies on the Adsorption of Cd (II) and Zn (II) ions from Aqueous Solutions onto Bottom Ash, *International Journal of Environmental Science and Development*, **5(2)**, 165-170 **(2014)**

12. Gupta S.S., Treatment of water contaminated with Pb(II) and Cd(II) by adsorption on kaolinite, montmorillonite and their acid-activated forms, *Indian Journal of Chemical Technology*, **16**, 457-470 **(2009)**