REMOVAL OF CADMIUM FROM AQUEOUS SOLUTION BY SORBENTS PRODUCED FROM PLANT WASTES

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ABSTRACT

The ability of natural adsorbents (MM, IC and CHF) to remove cadmium from synthetic wastewater was evaluated by comparing with PAC. All experiments were carried out under batch mode. The influence of initial metal concentration has been studied. The order of cadmium removal was found as PAC>CHF>IC>MM. The percentage removal of cadmium at 5ppm by CHF, IC and MM was 88.2, 73.6 and 33.4 respectively. As the metal ion concentration increases, the percentage removal of cadmium decreases. The high percentage removal at low metal ion concentration and low production cost make IC and CHF the attractive sorbents for the removal of cadmium from waste streams.

INTRODUCTION

Removal of toxic cadmium from water and wastewater has gained more attention lately. The tremendous increase in the use of cadmium mainly from metal plating, cadmium-nickel battery industries, mining, pigments, stabilizers and alloys has resulted in an increase of cadmium in aquatic environment (Low and Lee, 1991). Small amount of Cd(II) are believed to be harmful to aquatic lives and human health. Treatment processes for cadmium contaminated waste streams include chemical precipitation, electroflotation, membrane process, ion exchange, reverse osmosis, electrolytic methods and adsorption on activated carbon. These methods have been found to be limited because they often involved high operational costs, high energy requirements, production of toxic sludge that also require disposal and may also be insufficient to meet regulatory requirements. For that reasons, the use of low cost materials as adsorbent for cadmium removal from wastewater has been highlighted.

In general, an adsorbent can be assumed as low cost if it requires little processing, is abundant in nature, or is a byproduct or waste materials from another industry. Natural materials that are available in large quantities or certain waste products from industrial or agricultural operations may have potential as inexpensive adsorbents. Materials that have been investigated are rice straw, sugarcane bagasse, soybean and cottonseed hulls (Snoeyink and Summers, 1999), chitosan (Juang and Shao, 2002), bone powder and Nile rose plant (Abdel-Halim et al., 2003), fly larva shells (Gyliene et al., 2002), peanut shell (Chamarthy et al., 2001) and Pinus pinaster bark (Vazquez et al., 1998). A full description of low cost adsorbents for water and wastewater treatment: a review has been presented by Bailey et al. (1999). Plant wastes particularly Melastoma Malathrium (MM), Imperata Cylindrica (IC) and coconut hust fiber (CHF) are very common in Malaysia due to their high availability. In this present work, the ability of these three types of natural adsorbents to remove cadmium from aqueous solution was investigated by comparing with powdered activated carbon (PAC).

MATERIALS AND METHODS

Media

Natural adsorbents were gathered from rubber estates in Rawang, Selangor. They were washed with deionized water to remove very fine particles and laid on trays. The adsorbents were dried in an oven at 110^0C for a period of 5 days, then ground with Cuisinart Mini-Mate Plus Chopper and screened through a sieve stack consisting of 74µm and 88µm sieves. The adsorbents were stored in airtight plastic containers and ready for use. PAC of geometrical mean size 70µm was supplied by Merck.

Adsorption studies

The synthetic wastewater sample, Cd(II) was prepared from $Cd(NO_3)_2$. The chemical was supplied by Fisher Chemical, ACS Certified. Stock solutions of cadmium (1000pm) were prepared and suitably diluted to the required initial concentrations. Batch mode adsorption studies were carried out to determine the adsorption of Cd(II) on the natural adsorbents. Tests were performed in 100ml conical flasks by agitating 1g of adsorbents with 50ml of cadmium solution of known concentration for 30 min in shaking water bath at 150rpm (30^oC). Adsorbate and adsorbent were separated by centrifugation at 3000rpm for 15 min. The heavy metal concentration in the supernatant was analyzed by atomic absorption spectrophotometer (Perkin-Elmer Analyst 400). Blanks containing adsorbents but without heavy metal were used for each series of experiments as controls. The percentage removal of heavy metal was calculated using the following relationship:

$$\text{Percentage removal} = 100(C_i - C_f)/ C_i$$

where C_i and C_f are the initial and final concentrations (in ppm) of cadmium, respectively. The average values of duplicate runs were obtained and analyzed.

RESULTS AND DISCUSSION

Table 1 and table 2 listed the adsorption of cadmium ion on four different kinds of natural adsorbents at 5ppm and 10ppm respectively. At the same experimental conditions, powdered activated carbon had the highest removal rate, MM had the lowest removal rate. They were 99.4% for powdered activated carbon and 33.4% for Melastoma Malathrium at 5ppm metal ion. Coconut hust fiber and Imperata Cylindrica proved to be good adsorbents since the percentage removal of cadmium at 5pm was above 70%. Analyses on the blanks found no cadmium, which indicate the major source of cadmium in this study was purely from the synthetic wastewater.The initial pH values of cadmium solutions at 5ppm and 10ppm were 2.56 and 1.85 respectively. All adsorbents had the affinity to adsorb hydrogen ions which resulted in the increase of pH values at the end of experiments. Aurora (1999) stated that in acidic solution, there was also a competition between protons and metal species for the surface site charge, which results in a lower adsorption of the sorbing metals.

The results showed that the percentage removal of cadmium decreases as the concentration increases. It is highly recommended to carry out further investigation on the uptake kinetics and the adsorption isotherms for these natural adsorbents in order to determine their rate of adsorption and adsorption capacities. Evans et al. (2002) observed that the initial uptake of cadmium by chitosan was rapid but

decreased on the order of a few hundred hours, depending on the initial cadmium concentration. The summary of percentage removal of cadmium is shown in figure 1.

TABLE 1: Removal of Cadmium at 5ppm

Adsorbents	Final pH	Final Concentration (ppm)	% Removal
Melastoma Malathrium (MM)	2.91	3.33	33.4
Imperata Cylindrica (IC)	5.72	1.32	73.6
Coconut hust fiber (CHF)	3.72	0.59	88.2
Powdered activated carbon (PAC)	6.50	0.03	99.4

TABLE 2: Removal of Cadmium at 10ppm

Adsorbents	Final pH	Final Concentration (mg/l)	% Removal
Melastoma Malathrium (MM)	2.91	7.95	20.5
Imperata Cylindrica (IC)	5.72	5.62	43.8
Coconut hust fiber (CHF)	3.72	5.23	47.7
Powdered activated carbon (PAC)	6.50	0.18	98.2

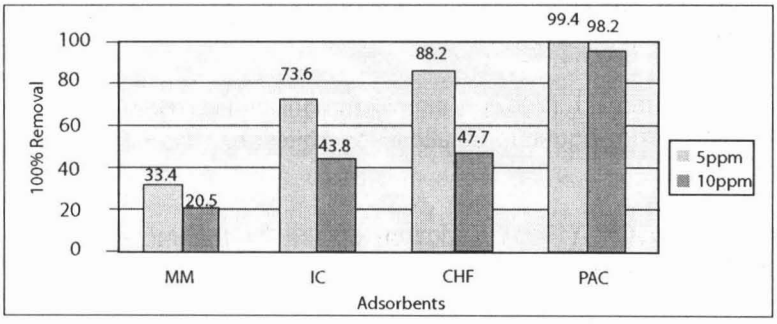

FIGURE 1: Percentage Removal of Cadmium by Adsorbents at Two Different Concentrations

CONCLUSION

It is found that CHF and IC have high adsorption for cadmium at lower concentration. The present study concludes that CHF and IC could be employed

as low cost adsorbents as alternatives to PAC for the removal of cadmium from water and wastewater.

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