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Original Research Paper

Copper and Cadmium Adsorption by Activated Carbon Prepared from Coconut Coir

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ABSTRACT

The study examined adsorption of copper and cadmium by the activated carbon prepared from coconut coir. Batch adsorption test showed that extent of metal adsorption was dependent on metal concentration, contact time, pH and carbon dose. Adsorption was low at acidic pH and increased with increase in pH. Adsorption capacity of the activated carbon for copper and cadmium was evaluated by adsorption isotherm test and compared with that of a commercial activated carbon. The coconut coir activated carbon showed higher limiting capacity for adsorption of copper and cadmium (84.74 mg/g and 68.03 mg/g) than that of the commercial activated carbon (46.30 mg/g and 14.90 mg/g).

INTRODUCTION

Toxic heavy metals have become an ecotoxicological hazard of prime interest and increasing significance owing to their tendency to accumulate in living organisms (Rao et al. 2006). Various techniques have been employed for the treatment of heavy metal waste, such as chemical precipitation, adsorption, electrolysis, ion exchange and reverse osmosis (Üçer et al. 2006). Adsorption appears to be one of the most promising techniques for the treatment of waste streams contaminated by metal ions (McKay 1995). According to a review by Huang (1978), activated carbons are capable of adsorbing metals include chromium, cadmium, mercury, copper, iron, zinc, nickel, vanadium, gold and silver (Santhy & Selvapathy 2004). However, high cost of commercial activated carbon limits its use in developing countries and there is a growing need to prepare activated carbon from locally available waste materials. Activated carbon prepared from agricultural wastes such as almond shells, olive stones and peach stones (Ferro-García et al. 1988), coconut coir pith (Santhy & Selvapathy 2004) and *Ceiba pentandra* hulls (Rao et al. 2006) have been studied for adsorption of copper and cadmium from aqueous solution.

Coconut coir is a residue in the processing of coconut and is available at minimal cost. It is rich in lignin (16-45%), hemicellulose (24-47%) and pectin (2%) content (Han & Rowell 1996, Conrad & Hansen 2007). The carboxylate and phenolic groups of lignin, hemicellulose and pectin are known as the main sites of metal binding (Conrad & Hansen 2007). In this study, activated carbon was prepared from coconut coir and adsorption of copper and cadmium from aqueous solution by the activated carbon was examined, and the adsorption capacity of the activated carbon was compared with that of a commercial activated carbon.

MATERIALS AND METHODS

Coconut coir activated carbon was prepared by soaking washed and dried coconut coir overnight in

10% potassium hydroxide solution, followed by washing with distilled water to remove free potassium hydroxide and drying at 105 ± 5°C for 24 h. It was then subjected to activation at 750°C for 30 min in an atmosphere of nitrogen. The carbon obtained was repeatedly washed with distilled water and then with 10% hydrochloric acid. The carbon was washed again with distilled water to remove the free acid and then dried at 105 ± 5°C for 24 h. The carbon was ground to a finer size of 0.2-0.3 mm and used in adsorption tests. A commercial activated carbon was obtained from the manufacturer and used as received in adsorption test.

Batch adsorption test was carried out by shaking 100 mL of copper or cadmium solution with 10 mg of activated carbon in a stoppered glass bottle placed in an orbital shaker at 150 rpm and room temperature (22°C). After a predetermined contact time, the bottle was removed from the shaker and the supernatant was filtered through 0.45μm membrane filter and analysed for copper or cadmium concentration by an atomic absorption spectrophotometer. The effect of contact time (1-6 h), metal concentration (20 and 40 mg/L), pH (3-10) and carbon dose (20-100 mg/L) on adsorption were evaluated by batch adsorption test.

Adsorption isotherm was determined by batch equilibrium test at the optimum pH and contact time for adsorption, with 100 mL of 10-100 mg/L of copper or cadmium solution and 10 mg of activated carbon.

RESULTS AND DISCUSSION

Effect of contact time: Effect of contact time and initial concentration on adsorption of copper and cadmium by the coconut coir activated carbon are shown in Fig. 1. Equilibrium adsorption is attained in 3 h. Santhy & Selvapathy (2004) reported similar results for adsorption of copper and cadmium by coir pith activated carbon. A contact time of 3 h was used in all subsequent adsorption tests.

Effect of pH: The pH is an important controlling parameter in the adsorption of metals because binding of metal ions by surface functional groups is strongly pH dependent (Lee & Davis 2001). Fig. 2 shows the effect of pH on adsorption of copper and cadmium from a 40 mg/L solution by the coconut coir activated carbon. Adsorption is low at acidic pH and increases with increase in pH. In the pH range of 3 to 6, linked H^+ is released from the adsorption sites and the adsorption of metal increases with pH (Üçer et al. 2006). It is believed that ion exchange and complex formation are the major mechanisms for adsorption of metal ions from solution (Üçer et al. 2005). Adsorption is dominant in the near neutral or less than neutral pH because metals precipitate as hydroxides in alkaline pH 8-11 (Benefield et al. 1982). Initial pH 6 was selected as optimum pH for adsorption of copper and cadmium by the activated carbon and all subsequent adsorption tests were conducted at pH 6.

Effect of carbon dose: Fig. 3 shows the effect of carbon dose on adsorption of copper and cadmium from a 40 mg/L solution by the coconut coir activated carbon. Adsorption increased with carbon

Table 1: Langmuir constants Q^o and b for copper and cadmium adsorption by coconut coir activated carbon and commercial activated carbon.

Activated Carbon	Copper		Cadmium	
	Q^o	b	Q^o	b
Coconut Coir Activated Carbon	84.74	3.37	68.03	4.74
Commercial Activated Carbon	46.30	0.09	14.90	0.19

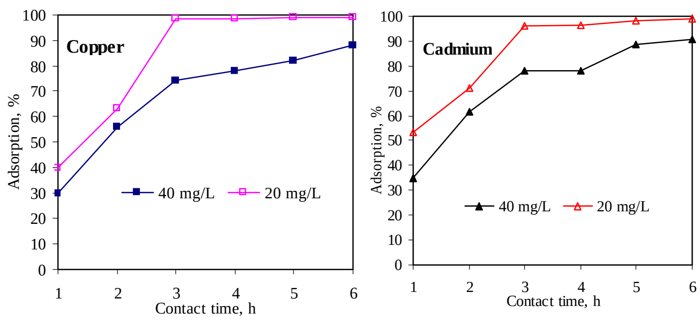

Fig.1: Effect of contact time and initial concentration on adsorption of copper and cadmium by coconut coir activated carbon.

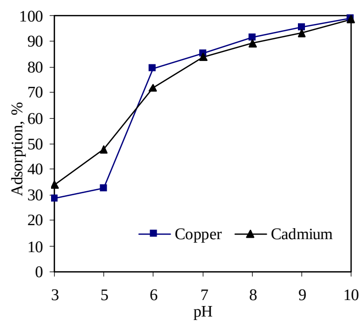

Fig. 2: Effect of pH on adsorption of copper and cadmium.

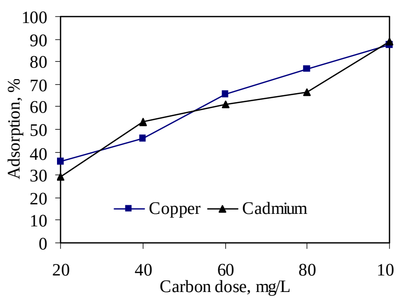

Fig. 3: Effect of carbon dose on adsorption of copper and cadmium.

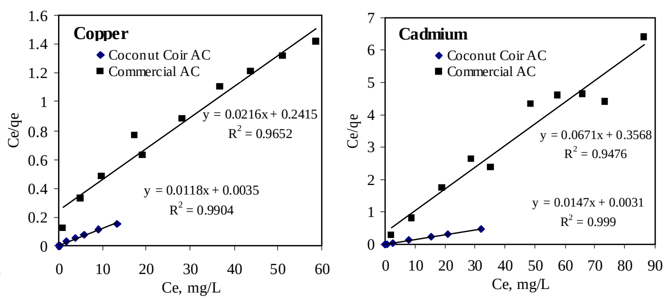

Fig. 4: Langmuir isotherm plot for adsorption of copper and cadmium by coconut coir activated carbon and commercial activated carbon.

dose and attained 90% at 100 mg/L carbon dose. Presumably, a higher dose of carbon would be required for near 100% adsorption.

Adsorption isotherm: In adsorption in a solid-liquid system, the distribution ratio of the solute between the liquid and the solid phases is a measure of the position of equilibrium. The preferred form of depicting this distribution is to express the quantity q_e as a function of C_e at fixed temperature, the quantity q_e being the amount of solute adsorbed per unit weight of the solid adsorbent, and C_e the concentration of solute remaining in solution at equilibrium. An expression of this type is termed an *adsorption isotherm* (Weber 1972). The Langmuir adsorption isotherm is $q_e = (Q^o bC_e)/(1 + bC_e)$ in which Q^o is the number of moles of solute adsorbed per unit weight of adsorbent in forming a complete monolayer on the surface and b is a constant related to the energy or net enthalpy. Although the basic assumptions explicit in development of the Langmuir isotherm are not met with in most adsorption systems of concern for water and wastewater treatment, the Langmuir isotherm has been found particularly useful for description of equilibrium data for such systems and for providing parameters (Q^o and b) with which to quantitatively compare adsorption behaviour in different adsorbate-adsorbent systems (Weber 1972). Rarely, does a value of Q^o represent a true monolayer capacity, but it does represent a practical limiting capacity for adsorption.

Adsorption isotherms of copper and cadmium adsorption by the coconut coir activated carbon and commercial activated carbon were fitted to the linear form of the Langmuir adsorption isotherm: $C_e/q_e = 1/bQ^o + C_e/Q^o$ (Fig. 4). The Langmuir constants Q^o and b for copper and cadmium adsorption by the coconut coir activated carbon and the commercial activated carbon are shown in Table 1. The coconut coir activated carbon showed higher limiting capacity for adsorption of copper and cadmium (84.74 mg/g and 68.03 mg/g) than that of the commercial activated carbon (46.30 mg/g and 14.90 mg/g).

CONCLUSION

The activated carbon prepared from coconut coir is suitable for adsorption of copper and cadmium from heavy metal waste. In adsorption test, the coconut coir activated carbon showed higher limiting capacity for adsorption of copper and cadmium than that of the commercial activated carbon.

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