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Application of Rice Husk and its Ash in Cadmium Removal from Aqueous Solution

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Abstract: The adsorption behavior of rice husk and its ash for cadmium ions from aqueous solutions has been investigated as a function of appropriate equilibrium time, amount of adsorbent, concentration of adsorbate, pH and particle size using a batch system. Studies showed that pH of aqueous solutions affected cadmium removal as a result of removal efficiency increased with increasing solution pH. The maximum adsorption was about 97.2 and 99.2% for rice husk and rice husk ash, respectively, at pH 6, contact time 180 min and initial concentration of 20 mg L^{-1}. Desorption of cadmium was 9% at pH 6. The cadmium sorption obeyed both the Langmuir and Fraundlich isotherms. The studies showed rice husk ash was more favorable than rice husk in removing cadmium and thus was a better adsorbent.

Key words: Cadmium, rice husk, ash, adsorption, removal, aqueous system

INTRODUCTION

Heavy metals are nowadays one of the most important pollutants in source and treated water and are becoming a severe public health problem. Heavy metal contamination exists in aqueous waste streams of many industries, such as metal plating facilities, mining operations and tanneries. The soils surrounding many military bases are also contaminated and pose a risk of metals ground water and surface water contamination. Some metals associated with these activities are cadmium, chromium, lead and mercury[1]. Heavy metals are not biodegradable and tend to accumulate in living organisms, causing various diseases and disorders[1,2]. Cadmium is a very toxic element affecting the environment. The toxic elements discharged in the effluents will be absorbed and accumulated by microorganisms. Eventually, the toxic element will get transferred to humans via the food chain. Human beings have reported nausea and vomiting at levels of 15 mg L^{-1} cadmium, with no adverse effects at 0.05 mg L^{-1}[3]. The treatment of cadmium contaminated water is similar to that of many metal contaminated effluents. There are several methods to treat the metal contaminated effluent such as precipitation, ion exchange and adsorption etc, but the selection of the treatment methods is based on the concentration of waste and the cost of treatment[2-5]. In the last few years, adsorption has been shown to be an economically feasible alternative method for removing trace metal from wastewater and water supplies[6-8]. Activated carbon has been the most used adsorbent; nevertheless it is relatively expensive[8-10]. Cost is an important parameter for comparing the sorbent materials. However, cost information is seldom reported and the expense of individual sorbents varies depending on the degree of processing required and local availability[1]. In general, a sorbent can be assumed as low cost it is requires little processing, is abundant in nature, or is a by product or waste material from another industry[1]. Activated carbon from cheap and readily available sources such as coal, coke, peat, wood, rice husk may be successfully employed for the removal of cadmium and other toxic heavy metals from aqueous solution[5]. Other adsorbents such as wood charcoal, red mud, sunflower stalks, petiolar felt-sheath and rice husk have also been used for the adsorption of cadmium[8,11-15]. The objective of this study was to explore the feasibility of rice husk and its ash as an adsorbent for the removal of cadmium from aqueous solution. The parameters that influence adsorption such as initial cadmium concentration, agitation time and pH were investigated.

MATERIALS AND METHODS

Preparation of sorbent: The rice husk used was obtained from the north part of Iran (in fall 2004). The rice husk were crushed and sieved with 40, 50, 60, 80 and 120 mesh

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sieve. Then, the husks were thoroughly washed with distilled water to remove all dirt and then were dried at 100°C to be constant weight. The dried husks were stored in desiccator until used. The rice husk ash obtained from burning of rice husk in electrical oven at 600°C for 3 h.

Chemicals: Stock solution of cadmium (1000 mg L^{-1}) was prepared by dissolving cadmium nitrate in distilled water. The concentration range of cadmium prepared from stock solution varied between 10 to 100 mg L^{-1} for both rice husk and its ash. Before mixing the adsorbent, the pH of each last solution was adjusted to the required value with diluted and concentrated H_2SO_4 and NaOH solution, respectively. All the chemicals used were of analytical reagent grade and were obtained from Merck.

Adsorption studies: Batch mode adsorption studies were carried out to determine the adsorption of cadmium. Each cadmium solution was placed in 1000 mL beaker and a known amount of adsorbents (0.5 to 10 g) were added to each beaker. The beakers were agitated on jar test equipment at a 100 rpm constant mixing rate for 3 h to ensure equilibrium was reached. Desorption study was carried out by taking 2 g of cadmium loaded adsorbent and 1000 mL of distilled water and agitating for 24 h at 100 rpm. pH of the desorbing medium (water) was adjusted to fix pH value 6 and percent desorption was determined. Finally the suitability of the Freundlich and Langmuir adsorption model to the equilibrium data were investigated for cadmium-sorbent system. All the experiments were carried out in duplicate and mean values are presented.

Analysis of cadmium: The residual cadmium was analysed through atomic absorption spectrometry using an ALPH-4-Flame atomic absorption spectrophotometer at wave lengths 228.8 nm using an acetylene-air flame according to standard methods[16].

RESULTS AND DISCUSSION

The adsorption of cadmium in aqueous solution on rice husk and its ash were examined by optimizing various physicochemical parameters such as pH, contact time, desorption, amount of adsorbent, adsorbent size and adsorbate.

Effect of initial pH: The percentage adsorption of cadmium on rice husk and its ash increased as pH of the solution was increased (Fig. 1) and reach to maximum value at pH 9. Adsorption of metal cation on adsorbent

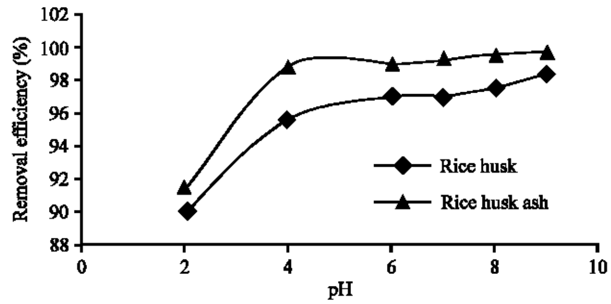

Fig. 1: Effect of the pH on the removal of cadmium by rice husk and rice ash husk (Adsorbent dosage = 2 g L^{-1} cadmium concentration = 20 mg L^{-1})

depends upon the nature of adsorbent surface and species distribution of the metal cation. Surface distribution mainly depends on the pH of the system[15]. The primary metal ion species in the pH range studied are Cd^{+2}, $CdOH^{+}$[17]. The percent adsorption of metal ion decreased with the decrease in pH, because protons compete with metal ion for sorption sites on the adsorbent surface as well as the concomitant decrease of negative charge of the same surface[15]. It has been reported that precipitation of cadmium starts at pH 8.3[5,15].

Effect of contact time: The adsorption of cadmium increased with increasing contact time and became almost constant after 45 min for rice husk and 30 min for its ash (Fig. 2). These results also indicate that the sorption process can be considered very fast because of the largest amount of cadmium attached to the sorbent within the first 30 min of adsorption. Similar results reported by Ajmal *et al.*[5] and Namasivayam and Panganathan[15].

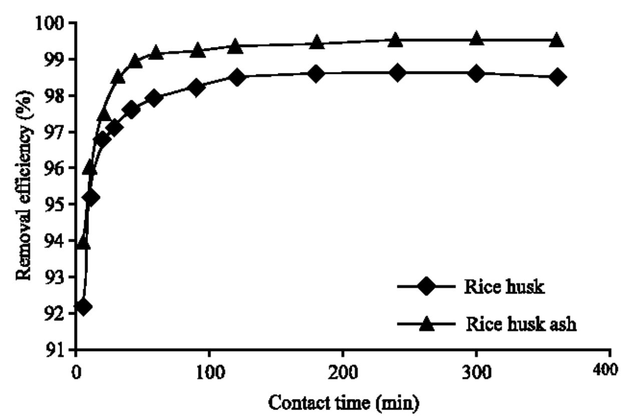

Fig. 2: Effect of the contact time on the removal of cadmium by rice husk and rice ash husk (Adsorbent dosage = 2 g L^{-1}, cadmium concentration = 30 mg L^{-1})

Effect of adsorbent amount: Figure 3 shows the removal of cadmium by rice husk and its ash at the solution pH 6. The percentage adsorption increased from 95 to 97.8% for rice husk and from 96 to 99.4% for rice husk ash when adsorbents doses were increased from 0.5 to 10 g L^{-1} for both sorbates, but at the same time adsorption density decreased from 38.02 to 1.95 mg g^{-1} for rice husk and from 38.4 to 1.99 mg g^{-1} for its ash. Similar results reported by other researcher[2,4,15].

Effect of initial concentration: As seen from results, the sorption capacities of the sorbents increased with increasing cadmium concentration while the adsorption yields of cadmium showed the opposite trend (Fig. 4). Increasing the mass transfer driving force and therefore the rate at which cadmium ions pass from the bulk solution to the particle surface. This would results in higher adsorption[4,8,15].

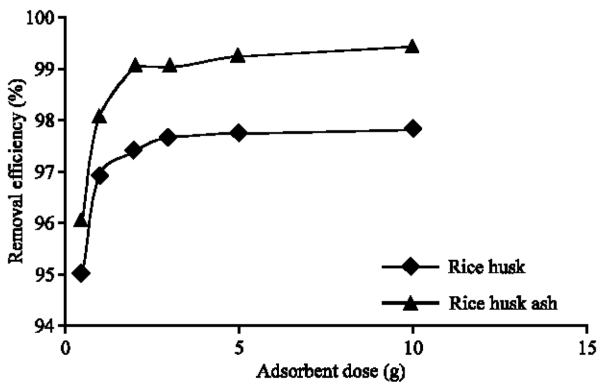

Fig. 3: Effect of adsorbent dose on the removal of cadmium by rice husk and rice ash husk (pH = 6, cadmium concentration = 30 mg L^{-1})

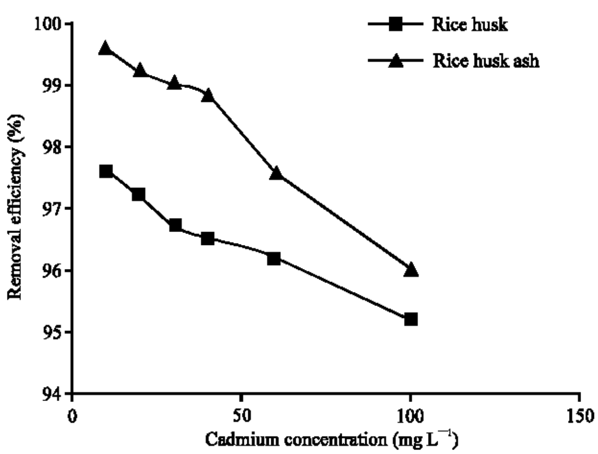

Fig. 4: Effect of the cadmium concentration on the removal of cadmium by rice husk and rice ash husk (Absorption dosage = 2 g L^{-1}, pH = 6)

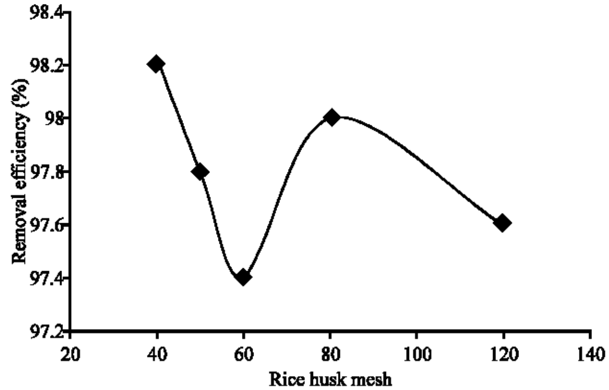

Fig. 5: Effect of rice husk size on the removal of cadmium (Cadmium concentration = 20 mg L^{-1}, rice husk dose = 2 g L^{-1})

Effect of particle size: The batch adsorption experiments were carried out using the six particle size at fixed pH 6, adsorbent dose 2 g, contact time 3 h. The selected particle mesh sizes were 40, 50, 60, 80 and 120. The percentage adsorption of cadmium was found to be 98.2, 97.8, 97.4, 98, 97.5 and 96.7 using the above-mentioned size, 40 was selected for adsorption studies due to the sufficient adsorption capacity and easiness of preparation (Fig. 5).

Desorption studies: Desorption studies help recycling of the adsorbent and recovery of metal. The batch desorption experiment were carried out using distilled water at fix pH value, adsorbent dose 2 g and contact time 24 h. The results showed that the desorption of cadmium by batch process was 9%. Similar results obtained by Namasivayam and Panganathan[15]. Other experiments showed that the percent desorption of cadmium increased with decrease in pH value. At acidic conditions, H^+ ions protonate the adsorbent surface leading to the desorption of the positively charged metal ion species[15].

Adsorption isotherms: Two models, Langmuir and Frendlich equations, were used to determine adsorption of cadmium onto rice husk and its ash. Isotherm studies were then carried out as described in our earlier study[8]. The related parameters of Langmuir and Frendlich models are summarized in Table 1.

The adsorption capacity (Q°) and energy of adsorption (b) were determined from the slope and

Table 1: Parameters of Freundlich and Langmuir isotherm models

	Freunjdlich constants			Langmuir constants		
	K	1/n	R^2	Q^0	b	R^2
Rice husk	15.03	0.8	0.998	58.14	0.037	0.995
Rick husk ash	23.7	0.46	0.982	27.47	5.35	0.955

intercept of the Langmuir plot and found to be (Q°) 58.14 and 27.47 and (b) 0.37 and 5.35, onto rice husk and its ash, respectively.

The Frendlich isotherm was also used to explain observed phenomena. K and n values were calculated from the intercept and slope of the plot and found to be (K) 15.03 and 23.7 and (1/n) 0.8 and 0.46 onto rice husk and it's ash, respectively.

The Freundlich isotherm is obeyed better than the Langmuir isotherm as is evident from the values of regression coefficients (Table 1). The results are given in Fig. 6 and 7. Similar results were reported by Ajmal *et al.*[5].

The ability of rice husk and its ash to adsorb cadmium from aqueous solution has been explored. The extent of removal depended on concentration of the adsorbate, pH, contact time and adsorbent amount. pH of aqueous solutions affected cadmium removal. That is, removal efficiency increased with increasing solution pH.

The maximum adsorption was about 97.2 and 99.2% for rice husk and its ash respectively at optimum condition. The adsorption process followed the Frendlich isotherm. The results showed that rice husk and its ash might have been successfully used as an adsorbent for the removal of cadmium from aqueous solution. Moreover, rice husk ash has adsorption capacity more than rice husk for cadmium removal.

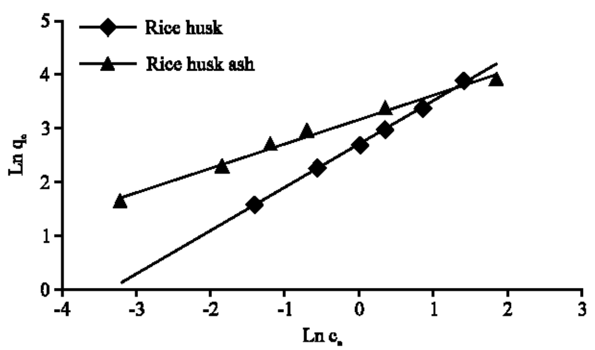

Fig. 6: The linearized Freundich adsorption isotherm for cadmium by rice husk and rice husk ash

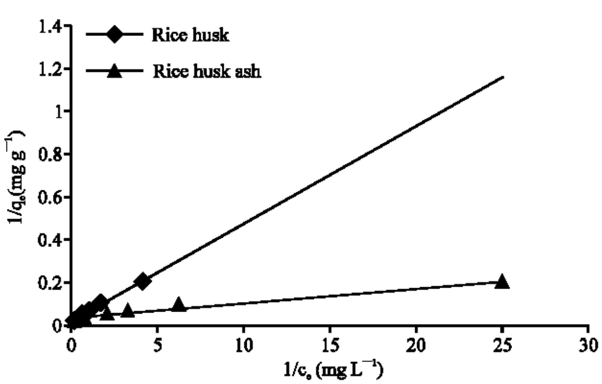

Fig.7: The linearized Langmuir adsorption isotherm for cadmium by rice husk and rice husk ash

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