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REMOVAL OF LEAD AND CADMIUM IONS FROM AQUEOUS SOLUTION BY ADSORPTION ONTO *Jatropha curcas* ACTIVATED CARBON

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Abstract

Lead and cadmium are among the heavy metals linked most often to human poisoning. They have the ability of dissolving in wastewaters and when discharged into surface waters, they can be concentrated on aquatic lives and materials. The Adsorption capacity of activated carbon prepared from *Jatropha curcas* husk (JAC) was carried out in removing the ions of these metals from aqueous solution. This was also compared with that of commercial activated carbon (LAC). Batch adsorption experiments were carried out to investigate the effect of parameters such as pH, contact time, adsorbent dosage, and initial concentration of the ions. Adsorption varied with increase in initial concentration of each ions with optimum adsorption at a particular initial concentration for each ion. The result shows that the two adsorbents removed Lead and Cadmium ions adequately following the order LAC (97.8% Pb(II) ion and JAC (98.2% Pb(II) ion and LAC (95.5% Cd (II) ion and JAC (97.00% Cd (II) ion. Adsorption of Pb (II) and Cd (II) ion decreases with increase in pH, varies with increase in Adsorbent dosage and increases with increase in temperature. The data fitted on Langmuir adsorption isotherm as evidence by their higher values of R^2 , LAC (0.998) and JAC (0.998) for Adsorption of Lead ion and LAC (0.999) and JAC (0.995) for Adsorption of Cadmium ion. The result shows the JAC as an adsorbent made from agricultural waste of *Jatropha curcas* could be effectively employed in the adsorption of lead and cadmium ions.

Key Words: Heavy metal, Adsorption, *Jatropha curcas* husk, Activated carbon

Introduction

Heavy metals are one of the most persistent pollutants in water (Mohan and Pittman, 2013). Unlike other pollutants, they are difficult to degrade, but can accumulate through the food chain, producing potential human health risks and ecological disturbances. They get into water through discharges from residential dwellings, groundwater infiltration and industrial discharges. The discharge of wastewater

containing high concentrations of heavy metals to receiving water bodies has serious adverse environmental effects, due to accumulation of heavy metal in the body of aqueous lives (Akpore and Muchie, 2010). Their occurrence and accumulation in the environment is a result of direct or indirect human activities, such as rapid industrialization, urbanization and anthropogenic sources (EPA, 2000; Hussein *et al.*, 2005).

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Heavy metal pollution is a global issue, although severity and levels of pollution differs from place to place. Lead and cadmium are particularly among the common heavy metals that have been identified in polluted water. The release of these metals without proper treatment poses a significant threat to public health because of their persistence, biomagnifications and accumulation in food chain. Severe effects include reduced growth and development, cancer, organ damage (Hussein *et al.*, 2005)

Different methods have been used in removing metals from water and waste water. Some of the techniques which have been used in the removal of metals from effluents include ion-exchange, chemical precipitation, bio-remediation, electrolytic extraction, reverse osmosis and cementation. (Wong *et al.*, 2003; Han *et al.*, 2007; Santhi *et al.*, 2010). When compared to the aforementioned methods, adsorption was accepted to be most efficient and more economical technique for the removal of metals from aqueous solution. The most widely used adsorbent is the activated carbon due to their low cost, and ability to be expended, and be disposed of without expensive regeneration (Malik, 2003; Gabaldon *et al.*, 1996; Madukasi *et al.*, 2001). *Jatropha curcas* has been a versatile crop, but information about the use of *Jatropha* seed husk, which is about 39% of *Jatropha* seed and fruit pericarp, is very limited (Vyas and Singh, 2007).

This work therefore employed and determine the potential of activated carbon produced from the seed coats of *Jatropha curcas* in removing lead and cadmium ions from the metal ions simulated waste water. The adsorption potential of this activated carbon is also compared with a commercial activated carbon (a laboratory activated charcoal which is a bone charcoal LAC).

MATERIALS AND METHODS

Jatropha curcas husk were collected from *Jatropha* plantation, University of Ilorin. The fruits are 2.5 cm long, ovoid, black and 2–3 halved. The plant has nearly 422 fruits per kg weight available for decortications of *Jatropha* seed for oil extraction. Laboratory activated carbon was collected from chemistry laboratory, University of Ilorin. All the chemicals used were of analytical reagent grade. These include: Orthophosphoric acid, 1% methylene blue solution Lead nitrate, Cadmium chloride, Hydrochloric acid (0.1M), Sodium hydroxide(0.1M) concentrated Nitric acid (0.1M), and de-ionized water. The activated carbon was obtained by chemical activation method as it has been observed to produce better results (Banat *et al.*, 2003). This was carried out by washing the husk with distilled water, sun dried and oven dried at 105 °C for 1hr. The carbonization was done in a muffle furnace at 300°C for 2 hrs. The charred products were grinded and using sieved to particle size of 0.25mm. The activation was carried out using activation agent orthophosphoric acid. The charred sample was soaked in 500cm³ of 0.1M orthophosphoric acid. The mixture was heated with continuous agitation for uniform activation until a paste was formed. This was transferred into a crucible and placed in a muffle furnace fixed at 500°C for two hours after which the charcoal was washed with distilled water, spread on a tray at room temperature to be drained and finally dried in an oven at temperature of 110°C for three hours.

Adsorption study

The adsorption potentials of the activated carbon were determined following the reported methods of (Okeola and Odebunmi, 2010; Nameni *et al.*, 2008). In this method batch sorption experiments were carried out at room temperature on a mechanical shaker. Working solutions of the solutes were

prepared from stock solutions, a known amount of activated sample was added to the solutions of particular metal ion in a conical flask. The flask is shaken for 1hr. for thorough mixing. The mixture was filtered and the post adsorption concentration of the solution was determined in the filtrate (Nameni *et al.*, 2008; Omomnhenle *et al.*, 2008). The percentage of the salt removed was determined following the methods of using the following equation:

$$\text{Adsorbate removed mg/g} = (C_i - C_f) V/m$$

$$\% \text{ adsorbate removed} = (C_i - C_f) / C_i \times 100$$

where C_i and C_f are pre and post adsorption concentration respectively, m , mass of adsorbent dose and V , volume of adsorbate solution. Effect of variation of various factors on adsorption was determined, such as variation in medium pH, initial concentration of adsorbate, adsorbent dosage and contact time. Adsorption equilibrium was determined and adsorption isotherms were constructed

RESULT AND DISCUSSION

The Effects of Initial Concentration of lead and cadmium ions ion Adsorption

Figure 1 shows that the percentage of Pb (II) ions and Cd (II) ions adsorption is significantly influence by the initial concentration of these ions in aqueous

solution, the adsorption of each ion follows similar pattern. Adsorption rise to a maximal as the solution concentration increase which then drop. The adsorption with respect to increase in initial concentration follows an open downward parabolic pattern for Pb (II) ions and sinusoidal for Cd (II) ions. Cadmium ions to JAC shows significant decrease of adsorption than Pb (II) ions to LAC. In a similar report this was due to high initial concentrations of Pb (II) and Cd (II) ions available to the surface. This accordingly makes the functional adsorption become depended on initial concentration (Tangjuank *et al.*, 2009). For Pb (II) ions JAC has the highest percentage uptake of 98.20 at optimum concentration of 15 ppm while the LAC has its highest at 97.88 at concentration of 20ppm and 25ppm respectively. For Cd (II) adsorption, JAC has the highest percentage uptake of 95.50 at optimum concentration of 10 ppm while the LAC has its highest percentage of 97.06 at concentration of 10ppm and 15ppm respectively.

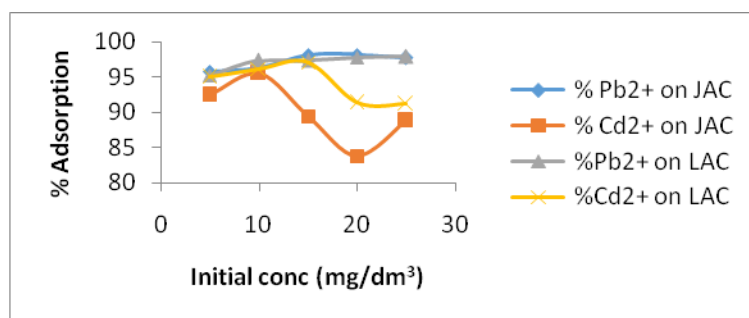


Fig.1 Effect of Initial Concentration of Pb(II) and Cd (II) adsorbates on the adsorption

Effect of adsorbent dosage on the adsorption

The effect of activated carbon dosage on adsorption of Pb^{2+} ion Cd^{2+} ions is shown in Figure 2. It was observed that with a general increase in the adsorbent dose from 0.5g-2.5g,

there is an increase in uptake level. This might be due to increase in the surface area and the availability of more adsorption sites. A similar effect was observed by Olayinka *et al.* (2009)

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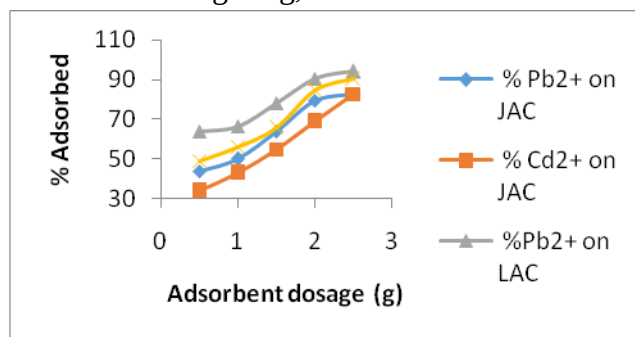


Fig.2 Effect of adsorbent dosage on the adsorption

Effect of pH of the medium on the adsorption

The pH of the aqueous solution is an important controlling parameter in the adsorption process. (Babu and Gupta, 2009). The effect of initial pH on the adsorption is exhibited in figure 3 with the maximum uptake occurring between pH of 2 and 4. Adsorption of Pb (II) ion on each activated

carbon follows the same pattern just as the case with the adsorption of Cd (II) ions. The observation was based on the excessive protonation of the active site competing with the ions. At low pH and at moderate pH values (2-4), H⁺ ions were released which allowed the adsorption of metal ions. At higher pH, metal precipitation was dominant (Senthil and Gayathri, 2009).

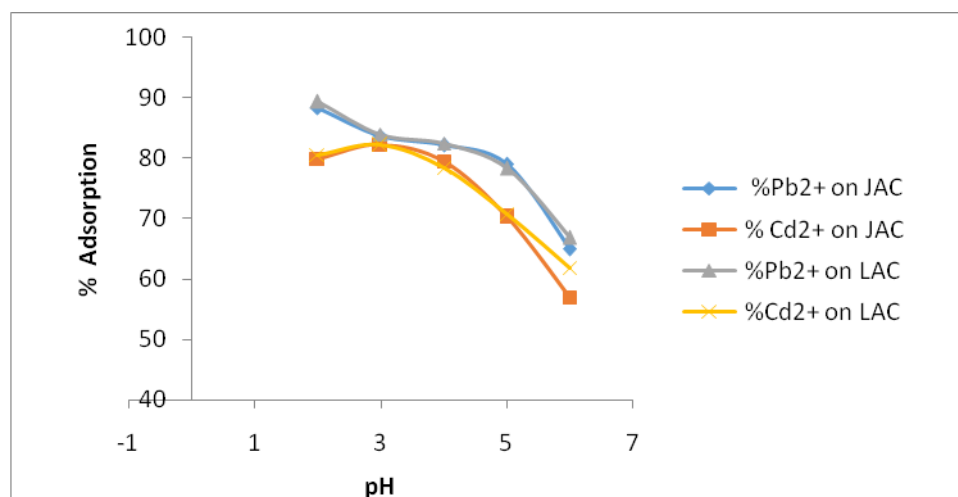


Fig.3 Effect of pH on adsorption.

Effect of contact time on adsorption

The influence of contact time on the adsorption capacity of the two activated carbons is shown in Fig 4. Adsorption increases as the contact time increases, the result clearly show that the rate of adsorption for the two activated carbons is higher at the

beginning which may be due to availability of a large number of active sites on the adsorbent. As the sites become exhausted, the uptake rate depends on the rate adsorbate transportation from the outside to inside the adsorbent particles (Senthil and Gayathri, 2009).

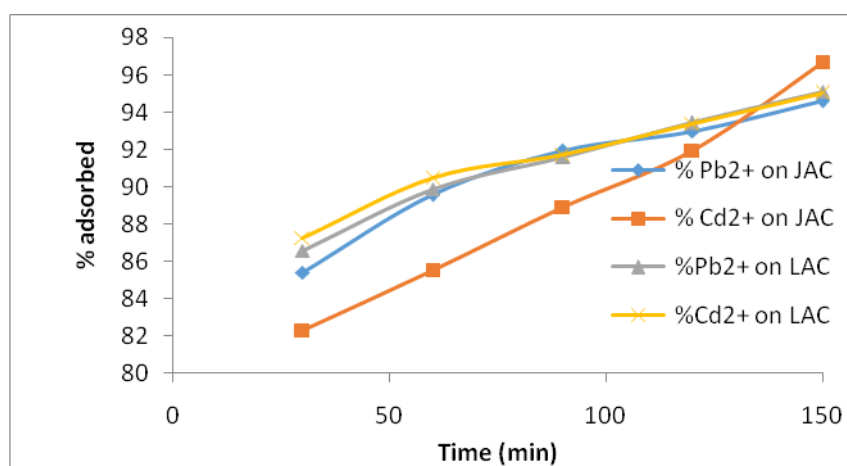


Fig 4. Effect of contact time on adsorption

Adsorption Isotherms Study

The capacity of adsorption isotherm is fundamental and plays an important role in the determination of the maximum capacity of

adsorption. The experimental data were fitted to linear form of Langmuir isotherms. Figures 5a & b and 6a & b shows the Langmuir models for adsorption JAC and LAC

respectively. The results of the analysis show that the data fitted for both adsorbent (JAC and LAC). Langmuir isotherms constants were presented in Table 1. The value of R^2 (Regression Correlation Coefficient) nearer to 1 indicates that the respective equation better fits the experimental data (Olayinka *et al.*, 2007). The Langmuir constants obtained were

compared with those of other adsorbents for Pb(II) and Cd(II) ions (Table 2). The observation shows that JAC has a good potential in removing lead and cadmium ions from the aqueous solutions. (Tangjuank *et al.*, 2009). However JAC shows preferred Pb(II)ions adsorption than Cd(II)ions.

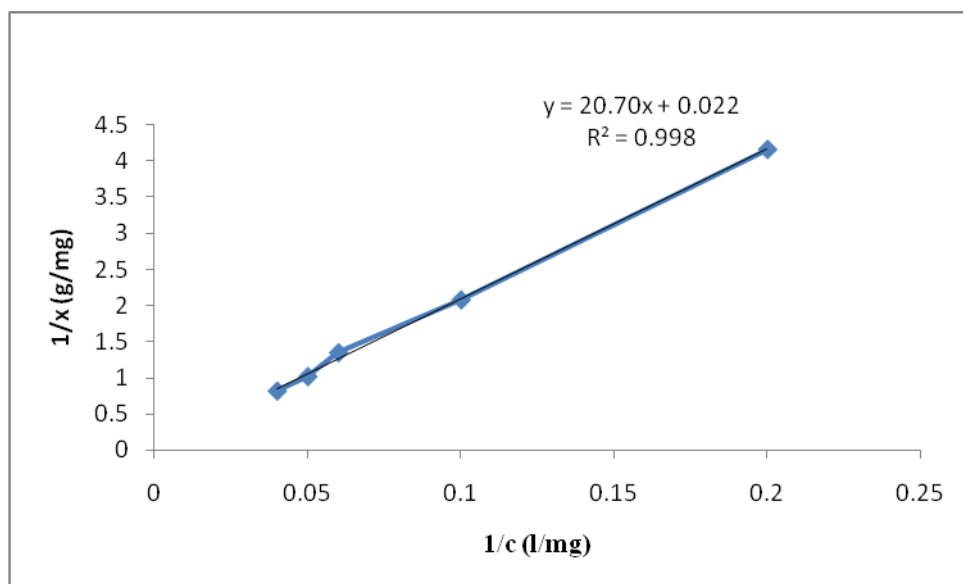


Fig. 5a Langmuir Isotherm for Adsorption of Pb (II) ion on JAC

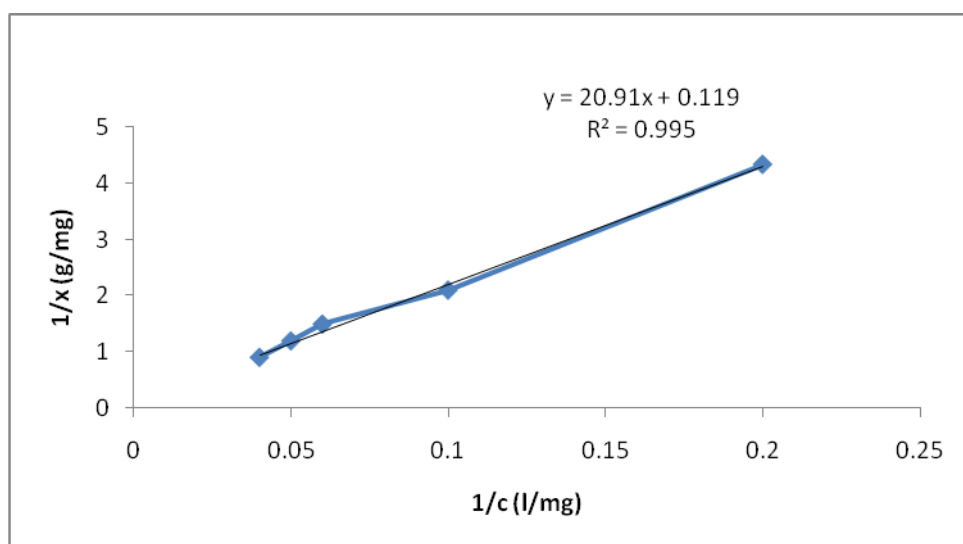


Fig. 5bLangmuir Isotherm for Adsorption of Cd (II) ion on JAC

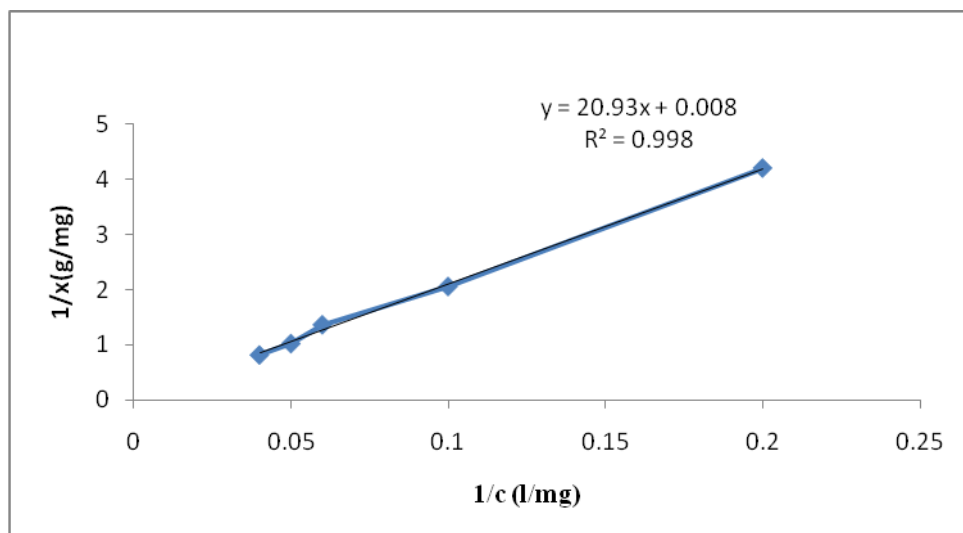


Fig.6a Langmuir Isotherm for Adsorption of Pb(II) ion on LAC

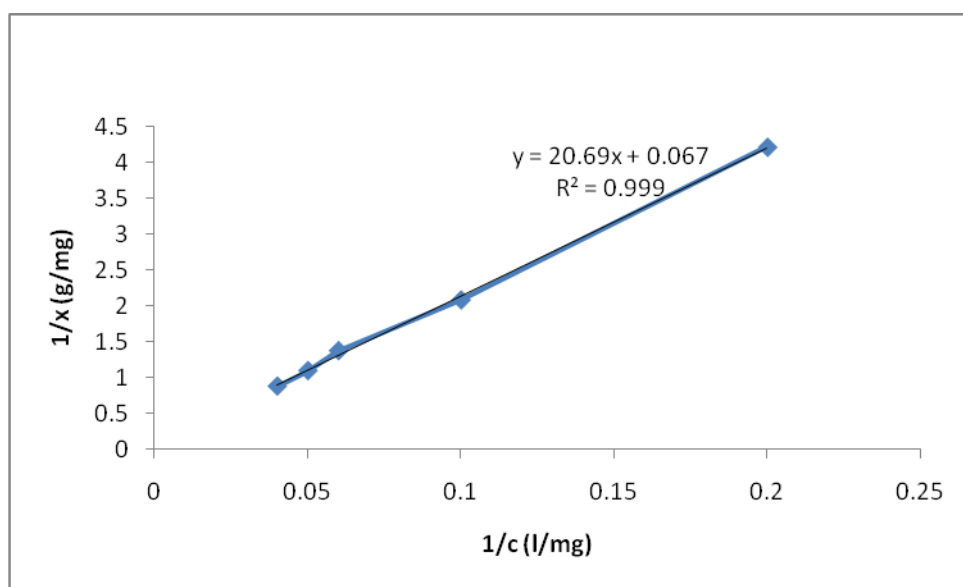


Fig. 6b Langmuir Isotherm for Adsorption of Cd (II) ion on LAC

Table 1. Values of Langmuir constants for adsorption of Pb (II) and Cd (II) ions

Activated Sample		$q_{\max}$ (mg/g)	K	R^2
Lead ion	JAC	44.05	1938.32	0.9987
	LAC	121.95	14017.24	0.9982
Cadmium ion	JAC	8.35	69.69	0.9959
	LAC	14.93	222.83	0.999

Table 2. Comparison of adsorption capacity of various sorbent for Pb (II) and Cd (II) ions

Adsorbent	$q_{\max}$ (mg/g)		pH	C_0 (mg/L)	Reference
	Pb (II)	Cd (II)			
Coconut shell carbon	26.50	-	4.5	50	(Sekar and Sakthi,2008)
Eichhornia activation	16.58	9.30	3.0	50	(Kadirveluet <i>al</i> ,2008)
Hazelnut husk A.C	13.05	-	5.7	40	(Immam and Tekir,2008)
Ceiba pentandra hulls	-	19.50	5.7	80	(Rao etal, 2006)
Cashew nut shell	28.90	14.29	6.0-6.5	40	(Tangjuank, 2009)

Conclusion

Jatropha curcas Activated Carbon may be used as adsorbent from abundant agricultural source for the removal of Pb(II) and Cd ions from aqueous solution. Pb (II) ions adsorption is more preferred to Cd (II) ions adsorption

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