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Removal of lead and cadmium in synthetic waste water using *phaseolus vulgaris* (beans) husk as bioadsorbent

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Abstract

The removal of heavy metals from wastewater and drinking water by the use of low cost bio-adsorbents is fast gaining research attention due to their effectiveness when compared with existing and expensive conventional methods such as ion exchange and membrane technology. Various agricultural wastes have been used in recent times for this bio-sorption process. In this study the readily available and cost effective husk of Phaseolus vulgaris, a local bean in southwestern Nigeria was used as adsorbent. The heavy metals concentration of the metal ion solution after adsorption was determined with Atomic Adsorption Spectroscopy (AAS). The result shows that removal efficiency of beans husk decreases with increase in initial concentration but increase with contact time and increasing adsorbent dosage. The adsorption capacity however increases with increase in initial concentration but decrease as adsorbent doses increase. The optimum pH for the adsorption of lead was 1.55 and 4.90 for cadmium. From the results, a cheap and cost effective adsorbent for the removal of heavy metals from waste water is achieved.

Keywords: Biosorption, *Phaseolus vulgaris*, adsorption capacity, removal efficiency, wastewater.

Introduction

The discharge of heavily polluted effluent containing toxic chemicals such as heavy metals into waterways is on the increase as a result of increase in industrial activities and growing population. Heavy metal refers to metals that has a relatively high atomic density (> 5g/cm^3) and is toxic or poisonous even at low concentrations. They are considered serious pollutants due of toxicity, persistency, and bio-accumulating tendency, which constitute threat to human life and the ecosystem[1-3]. Many studies have revealed the serious health problems caused by the presence of heavy metals in the environments. Severe damages to body organs such as dysfunction of kidney, reproductive system, liver, gastrointestinal, brain and central nervous system have been reported[4-6].

Based on this, heavy metals removal from wastewater before its discharge to the water bodies such as streams and rivers is of utmost necessity to safeguard human health and protect aquatic life and to ensure compliant with the permissible limits of these metals as stipulated by local and International regulatory bodies.

Some conventional methods have been employed in removing these toxic metals. These technologies include ion exchange, vacuum evaporation, membrane technologies, reverse osmosis, chemical precipitation and filtration, activated carbon adsorption, etc. However, these methods have been reported to have high operational cost, minimal removal efficiency, and production of sludge[7,8]. The removal of these heavy metals can alternatively be achieved by the use of cheap and eco-friendly materials. The use of agricultural wastes as low cost and easily available bio-adsorbent to remove heavy metals is fast gaining research attention and high removal efficiency have been reported. Agricultural wastes such as rice husk, rice bran, wheat husk, wheat bran, saw dust of various plants, bark of the trees, coconut shells, groundnut shells, seaweeds, moulds, yeasts, and other dead microbial biomass have been explored[9-13].

The agricultural wastes containing cellulose and lignin show potential metal bio-sorption capacity because of the various functional groups in their biomass that can bind heavy metals from solutions[14]. Agricultural wastes aside from being eco-friendly have lots of other advantages over the conventional methods which include, availability, abundance in nature, high efficiency, and utilization at low operating cost. In this study, *Phaseolus vulgaris* beans husk, locally called *Ewa Oloyin* (Yoruba Language) in the South-West Nigeria will be utilized in preparing the bio-adsorbent.

Material and Methods

Preparation of adsorbent: The *Phaseolus vulgaris* (beans) husk used in this study were collected from beans sellers at the main Bodija market in Ibadan, Nigeria. The beans husk were collected in a pre-cleaned polythene bag and kept in a dry cupboard. Debris and stone were separated from the beans husk by hand picking. The husk were then washed thoroughly with tap water and later rinsed with distilled water before sun drying. After sun drying, the husk were ground into powdery form and sieved to achieve more uniform particle size. The ground samples were then thoroughly washed with distilled water and oven-dried at a temperature of 70°C for 3 hours. The prepared adsorbent was stored in airtight container without further treatment and kept for future use.

Preparation of synthetic wastewater: The synthetic wastewater solution was prepared by measuring different volume from 1000mg/L stock solution of lead and cadmium salts and thereafter diluted into different concentrations.

Batch Experiment: A fixed amount of the adsorbent was added to a series of 250mL Erlenmeyer flasks containing 50mL diluted solutions (10–50mg/L). The flasks were then agitated on a magnetic stirrer for 1 hour at room temperature then removed and the concentrations of the metal ions in the solution were determined using the Atomic Absorption Spectrophotometer (AAS), Perkin Elmer A Analyst 200 model. The pH of the wastewater was adjusted with 0.1M NaOH and HCl solution. The effects of contact time, initial concentration, adsorbent dosage and pH on adsorption capacity and removal efficiency were determined. Adsorption Capacity, Q_e (mg/g) at equilibrium and the Removal Efficiency (R %) is calculated as stated below:

$$Q_e = \frac{(Co - Ce)V}{W}$$

Where: *C*o (mg/L) is the liquid phase concentration metal ions at initial, *C*e (mg/L) is the liquid phase concentration of the metal ions at equilibrium, *V* (L) the volume of the solution, and *W* (g) is the mass of adsorbent used.

The removal efficiency, R% is given below as

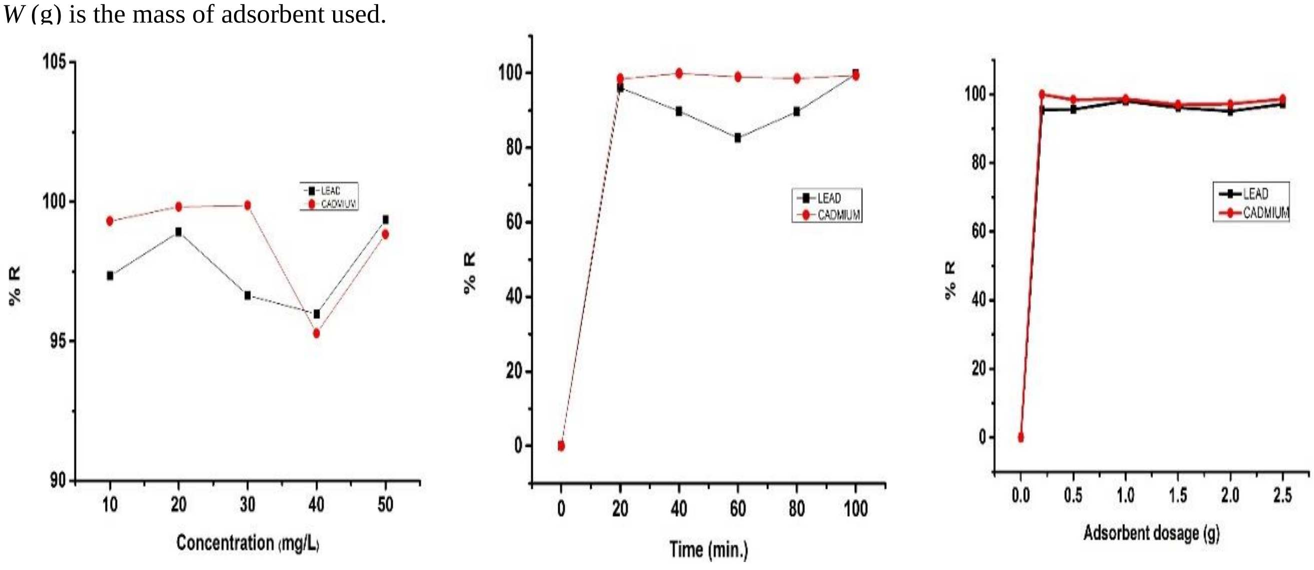
$$R\% = \frac{C_o - C_e}{C_o} \times \frac{100}{1}$$

Effect of contact time: About 50ml each of 10mg/L of both lead and cadmium ions solutions were measured into a 250mL Erlenmeyer flask and 1g each of the adsorbent was added to it. It was stirred with a magnetic stirrer at different time interval (20, 40, 60, 80, 100 minutes) at room temperature and then filtered.

Effect of initial concentration: About 1g each of the adsorbent was added into different 250ml Erlenmeyer flask containing varying concentrations of the metal ions solution (10, 20, 30, 40 and 50mg/L) and then stirred for 1hour using a magnetic stirrer at 200rpm at room temperature. The mixture was filtered and the filtrate poured into an air-tight plastic sample bottles for further analysis.

Effect of adsorbent dosage: The prepared beans husk (adsorbent) were weighed in different grams (0.2, 0.5, 1.0, 1.5, 2.0 and 2.5g), and each was added to a 50ml of 20 mg/L of the metal ions solution in a Erlenmeyer flask and then stirred for 1 hour with a magnetic stirrer at 200rpm. The mixture was filtered and the filtrate poured into a pre-cleaned air-tight plastic sample bottle.

Effect of pH of the solution: Exactly 1g each of the adsorbent was added to a 50 ml solution of 10mg/L of lead and cadmium in a 250ml Erlenmeyer flask and then agitated at 200 rpm for an hour with a magnetic stirrer and then filter. The filtrate was poured into air-tight plastic sample bottle.



(a) (b) (c)

Figure-1: The effects of (a) Initial concentrations (b) Contact time and (c) Adsorbent doses on removal efficiency.

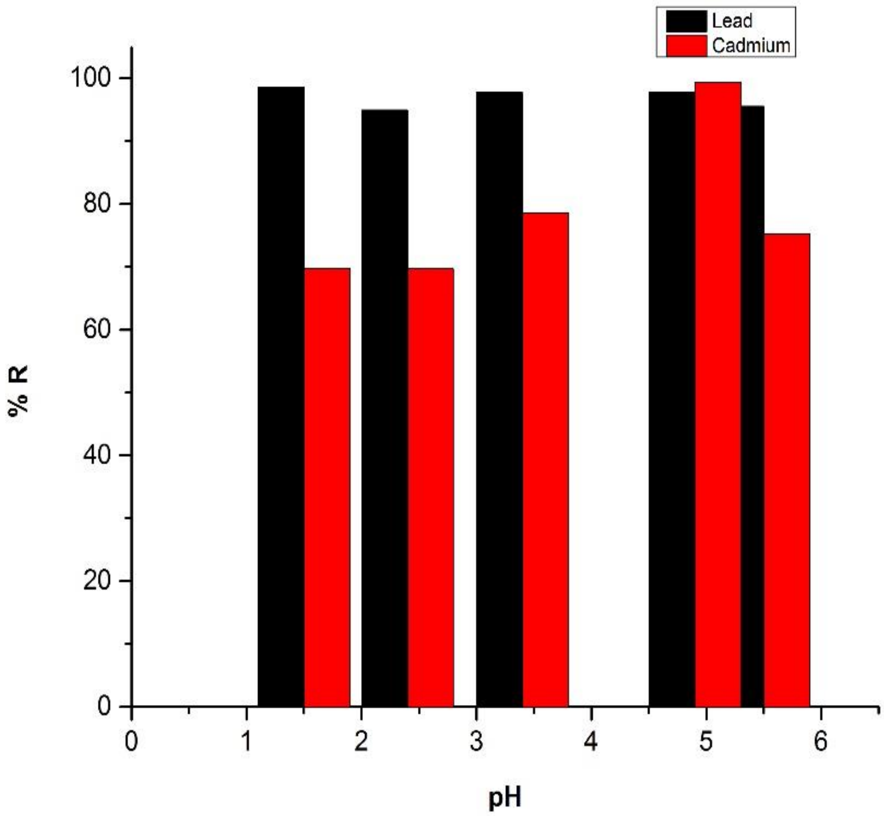
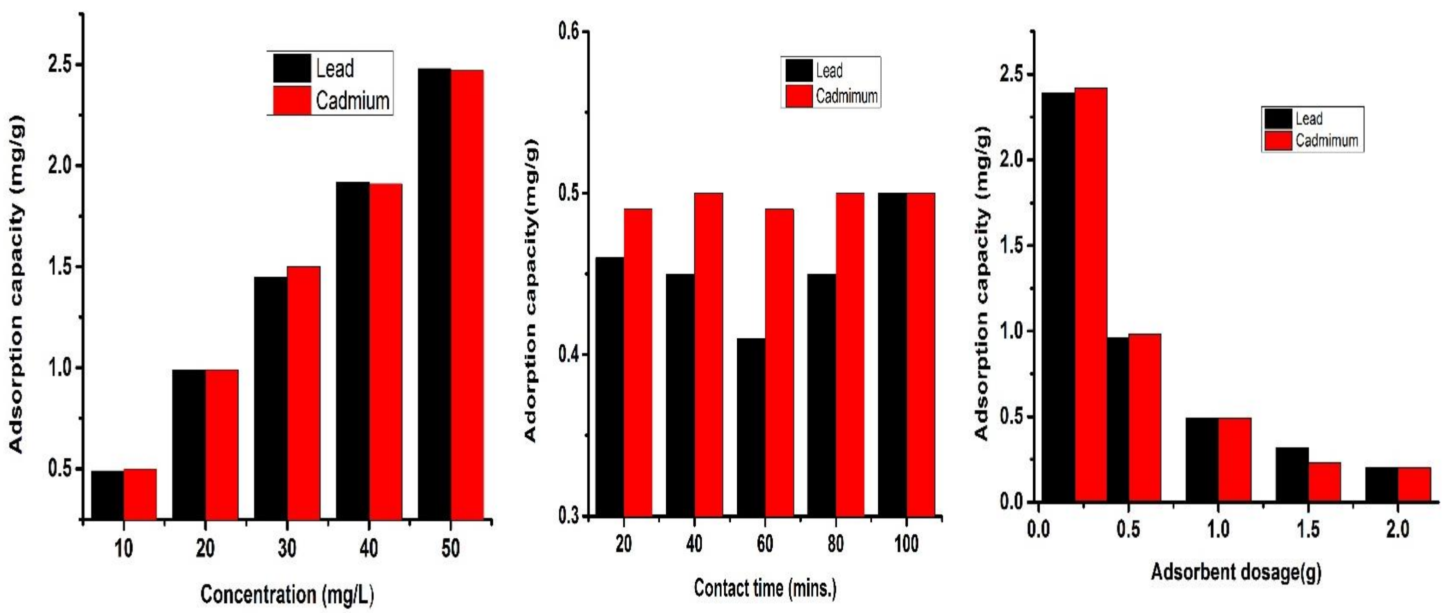


Figure-2: Effect of pH on percent removal of lead and cadmium from the metal ion solutions.



(a) (b) (c)

Figure-3: Effects of (a) Concentration (b) Contact time (c) Adsorbent dosage on adsorption capacity.

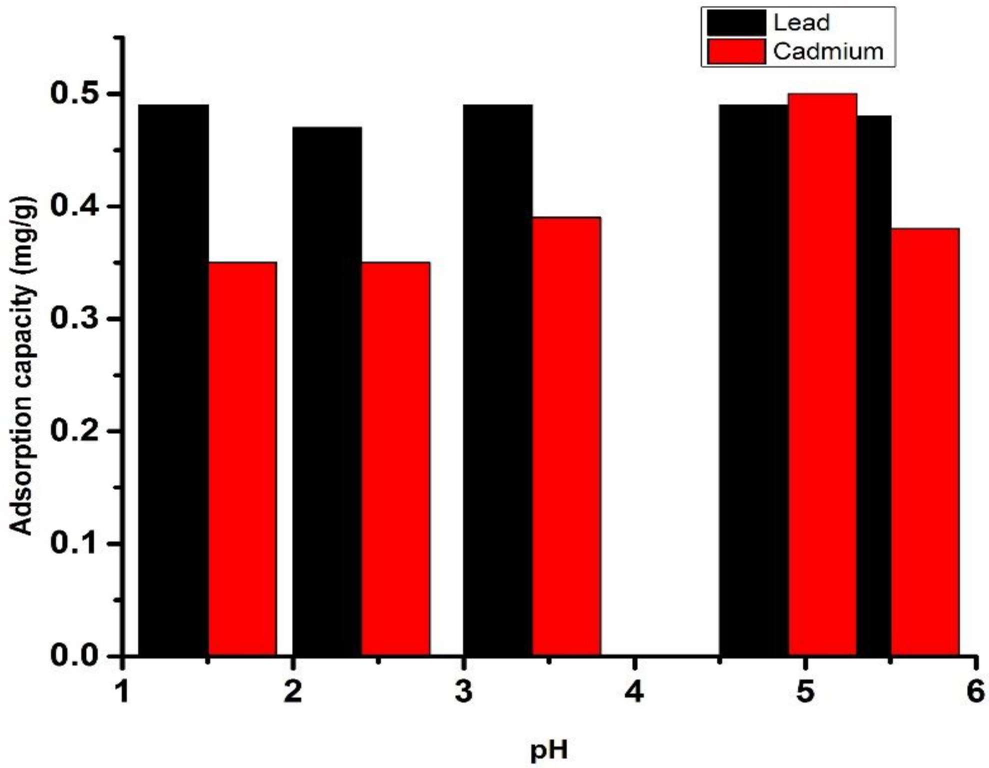


Figure-4: Effects of pH on adsorption capacity.

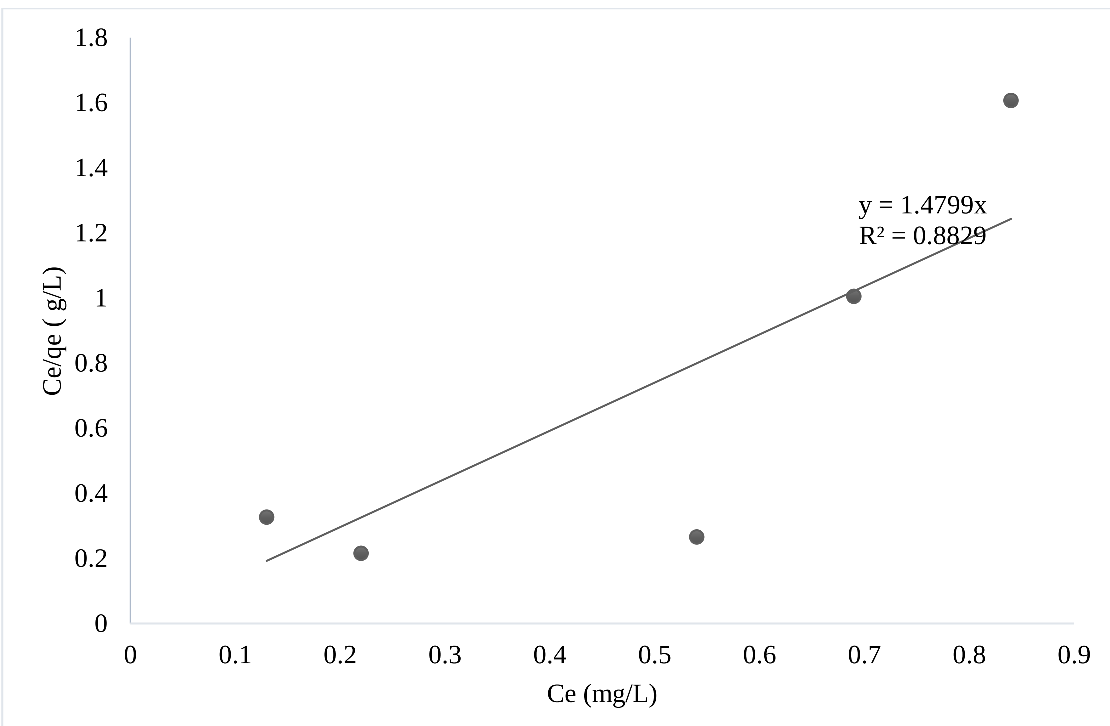


Figure-5: Langmuir isotherm for lead.

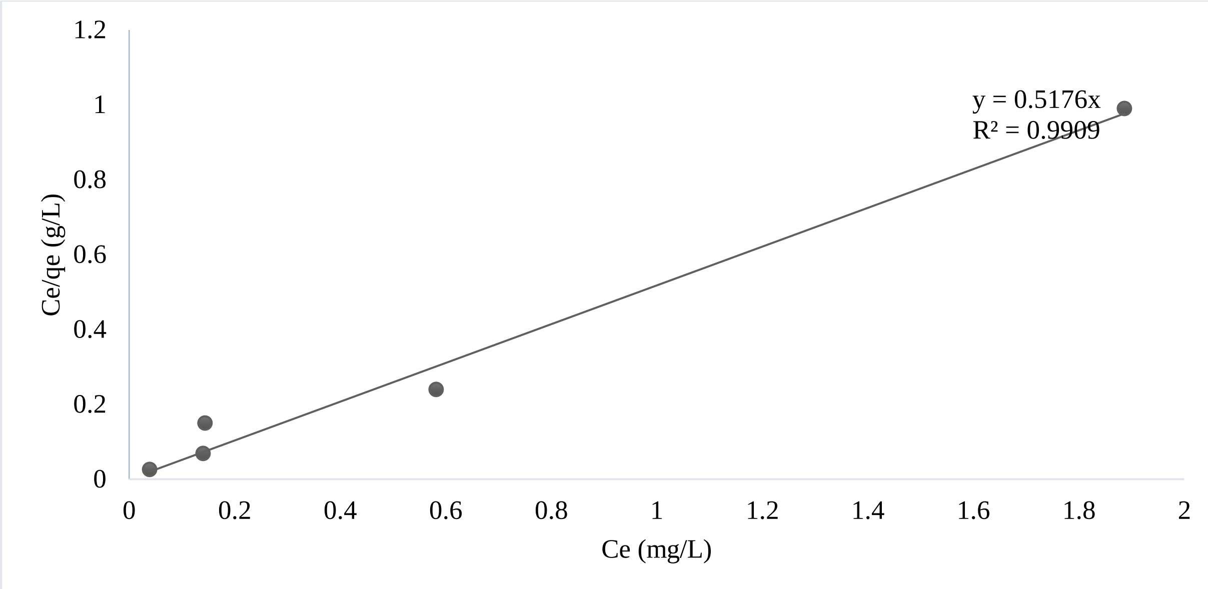


Figure-6: Langmuir isotherm for cadmium.

Results and discussion

The initial concentration of metal ions as observed in Figure-1a shows increase in removal efficiency at the initial stage but later decrease as the concentration increases. This could be due to unavailability of adsorbent unoccupied binding sites as concentration increases. The highest removal efficiency of the bean husk (adsorbent) on the removal of Pb^{2+} and Cd^{+2} was attained at concentrations of 50 mg/L and 30 mg/L respectively which correspond to 99.87% and 99.35%.

Figure-1b shows the dependence of lead and cadmium on contact time. Rapid increase was noticed at the beginning of the adsorption process, then a slight decreased followed by a constant removal efficiency. The initial increase was due to the large number of vacant adsorption sites available for adsorption at the beginning, as mixing time increases some bound metal ions re-dissolve into solution, thereby decreasing the removal efficiency[15].

Removal efficiency of 99% was attained at 100 minutes of contact time for both cadmium and lead. Increasing the adsorbent dosage however increases the removal efficiency in both ions (Figure-1c). More adsorbent surface area and adsorbent concentration could be attributed to this observation. The highest removal efficiency of cadmium was at 99% and that of lead was 97% at adsorbent dose of 0.2 g and 1 g respectively.

The percent removal for cadmium was higher than that of lead in all the parameters considered in Figure-2. The major parameters controlling the removal efficiency of adsorbent is pH. The optimum pH for the adsorption of lead ions was 1.5 which corresponding to removal efficiency of 98.63% as shown in Figure-2 and for cadmium was 4.9 corresponding to removal efficiency of 99.43%.

Adsorption capacity of Pb^{2+} and Cd^{2+} ions increase as initial concentration of metal ions increases in Figure-3a. The amount of metal ion adsorbed per unit mass of the adsorbent as a function of contact time is shown in Figure-3b, the adsorption capacity of Cd^{2+} ions by the beans husk was increase rapidly with increase in contact time then constant while that of lead had a drop at 60 minutes and it rises back, this was due to desorption of the metal ions and re-adsorption as mixing progresses. Figure-3c shows that adsorption capacity of cadmium and lead ions depend on adsorbent doses. The adsorption capacity decreases as the adsorbent doses increases.

The highest adsorption capacities were attained at pH 4.9 for cadmium ions and 1.5 for lead as shown in Figure-4. pH control adsorption capacity of metal ions.

Table-1: Langmuir equilibrium parameters for adsorption.

	K	q_m	R^2
Pb	0	1.934	0.9847
Cd	0	0.676	0.6972

Table-1 above shows the Langmuir equilibrium parameters for the adsorption process. The values of the regression coefficient (R^2) for the adsorption of Cd^{2+} and Pb^{2+} on to the adsorbent is 0.9847 and 0.6972 respectively. This suggests the homologous nature of adsorption of Cd^{2+} on to the surface of adsorbents. The q_m values, 1.934 for Cd and 0.676 for Pb, also indicate that the adsorbent exhibited higher adsorption capacity for Cd compared to Pb.

Conclusion

This study has revealed that the husk of *Phaseolus vulgaris* can be effectively used as a low cost and easily available adsorbent for removal of cadmium and lead ions from wastewater. Both the removal efficiency and adsorption capacity appeared to depend on pH. The optimum pH for cadmium ions was 4.9 while that of lead was 1.5. The adsorbent is more suitable for both ions but with more preference for cadmium. While contact time of 100 minutes gave the highest percent removal and adsorption capacity for the metal ions under consideration.

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