International Archive of Applied Sciences and Technology
Int. Arch. App. Sci. Technol; Vol 9 [4] December 2018 : 16-21

[ISO9001: 2008 Certified Organization]
www.soeagra.com/iaast.html

IAAST
ONLINE ISSN 2277- 1565
PRINT ISSN 0976 - 4828

CODEN: IAASCA ORIGINAL ARTICLE

DOI: .10.15515/iaast.0976-4828.9.4.1621

Removal of heavy metals from domestic water samples using low cost natural adsorbent

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ABSTRACT
Water samples were collected from 25 bore wells during pre-monsoon season from Ulhasnagar city. These samples were analyzed for dissolved metal concentrations with special reference to the concentration of Lead (Pb) & Cadmum(Cd). The toxic metals such as Cd, Cu and Cr were found to be present within permissible levels except Lead. The concentration of Lead was found to be 0.05mg/L to 1.1 mg/l which exceeded the permissible limit recommended by WHO. The present work deals with the use of plant material as almost zero cost bio adsorbent for the removal of Pb^{+2} & Cd^{+2} ions from the domestic water samples (Bore well water). This methodology offers cost effective and efficient alternative as compare to regular chemical and physical techniques. Adsorption studies of Pb^{+2} & Cd^{+2} ions on natural material were carried out by Batch experiments. The parameters studied include metal ion concentration, adsorbent dose, pH, contact time and temperature among which pH was found to be controlling adsorption of Pb^{+2} & Cd^{+2}.
Key-words - *Toxic metals, Lead, Cadmium, bio adsorbent, Batch experiment, cost effective.*

Received 28/07/2018 Revised 25/08/2018 Accepted 04/10/2018

Citation of this article
Nagesh Raghunath Sutar. Removal of heavy metals from domestic water samples using low cost natural adsorbent. Int. Arch. App. Sci. Technol; Vol 9 [4] December 2018. 16-21.

INTRODUCTION

Water samples were collected from 25 sampling sites that are domestic bore wells during the pre-monsoon season in Ulhasnagar city in Mumbai. Ulhasnagar is a medium size city in Mumbai Metropolitan region. It has a humid climate. The temperature varies between 27^0C to 34^0C during the summer and 8^0C to 31^0C in winter. Annual average rainfall over the city is 528mm. Twenty five sampling sites were identified for analysis during pre-monsoon season (March 2015 – May 2015). Samples were collected between 9.00 am to 4.00 p.m. in clean well-dried brown glass bottles with necessary precautions and stored at 4^0C to keep the composition of samples unchanged. The samples were analyzed for nineteen parameters. Physical parameters like pH, TDS were determined at the site with the help of digital portable TDS Meter and conductivity of water was determined using Conductometer in the laboratory. The chemical and microbial characteristics were determined as per the protocols of Methods for Examination of Water and Waste water.[1]
These samples were analyzed for dissolved heavy metal concentrations with special reference to the concentration of Lead (Pb) & Cadmium (Cd). The water samples were analyzed using Atomic Absorption Spectroscopy (AAS) technique. The toxic metals such as Cd, Cu and Cr were found to be present within permissible levels except Lead. The concentration of Lead was found to be 0.05mg/L to 1.1 mg/l which exceeded the permissible limit recommended by WHO (0.01mg/dm^3 World Health Organization Report, 1993). Such high concentration of Lead was found to be responsible for making water samples non-potable. The discharge of industrial effluents in water resources might be a

reason for pollution due to Lead. Such a high concentration of Lead results in the non-potability of water. All the samples are non-potable with respect to WHO and BIS-10500 (1993) standards. Lead, at certain exposure levels, is toxic, damages the nervous system and is a neurotoxin accumulating both in soft tissue and in bones. There is a recent report of renal failure with metal contamination in drinking waterB [2]. Similarly, the long term retention of cadmium in the body of leaving being was found to be responsible for ill-effects such as pulmonary edema, shortness of breathing etc as per WQA Technical Fact Sheet: Cadmium.

Common techniques used to remove heavy metal ions from industrial waste water have been reported in literature which include uase of techniques such as ion-exchange, reverse-osmosis, electro-coagulation, chemical precipitation, neutralization, and adsorption. These techniques exhibit high operational cost. Due to this, adsorption on low cost naturally available adsorbent for removal of toxic metals from water has been investigated extensively. These natural adsorbents include number of naturally occurring materials [3-10].

In the present study, we used some plant residues as Biosorbents for the removal of heavy metals such as Pb^{+2} & Cd^{+2} ions from bore well water. In the present study, we used powder of leaves of Jackfruit plant (*Artocarpus heterophyllus*) as Biosorbents for the removal of two divalent metal ions from domestic bore well water.

MATERIAL AND METHODS

EXPERIMENTAL

Adsorbents

Adsorbents used in the present study are Jackfruit plant (Artocarpus heterophyllus) leaf powder (JPLP). Mature Materials of above mentioned adsorbents are collected and washed thoroughly with distilled water to remove dust and other impurities. Washed materials are dried for 5-6 days in sunlight. Dried materials were ground in a domestic mixer-grinder. After grinding, the powders were again washed thoroughly to remove all colour and further dried. These powders were sieved through Jayantha's sieves and stored in plastic container for use.

Preparation of synthetic water sample

Synthetic water samples were prepared by using analytical grade lead nitrate and cadmium chloride. For pH adjustment throughout the experiment, hydrochloric acid and/or sodium hydroxide solutions were used as necessary. The stock solutions contained 100 mg/l of Pb(II) and Cd(II), respectively.

Batch experiments were performed at 27°C. The samples were mechanically agitated at 100 rpm. The concentrations of lead and cadmium were estimated using Shimadzu AA7000 with an acetylene-air flame system [11].

The proportion of heavy metal removed from solution was calculated using the following equation:

$$\frac{C_0 - C_e}{C_0} \times 100$$

Where, C_0 and C_e are, respectively, the initial and final concentrations of heavy metal.

The amount of adsorbed metal ions per unit mass of biomass was obtained from the following equation-

$$q_e = \frac{(C_0 - C_e)\,V}{m}$$

Where V is the volume of the medium, and m is the mass of natural material used.

RESULTS AND DISCUSSION

Effect of pH

The pH is one of the most important parameters of biosorption of heavy metals [12]. The biosorption of lead and cadmium by Jackfruit plant leaf powder at different pH values is presented in Fig. 1. In the present investigation, the rate of removal of Pb(II) and Cd(II) ions in synthetic wastewater was mainly controlled by pH of the solution. The optimal pH for

Pb(II) and Cd(II) removal was 4.3 and 4.7, respectively. At pH higher than 6, both metals were precipitated due to the formation of hydroxides and removal through biosorption was very low. At low pH, the concentration of protons was high and metal binding sites became positively charged repelling the Pb(II) and Cd(II) cations. With an increase in pH, the negative charge density on the biomass increases due to de-protonation of the metal binding sites, thus increasing metal biosorption. Similar results were found with tree fern where it has been shown that pH values in the range of 4.0 to 7.0 are adequate for lead binding, of which pH 4.9 is the optimum value for the biosorbent.

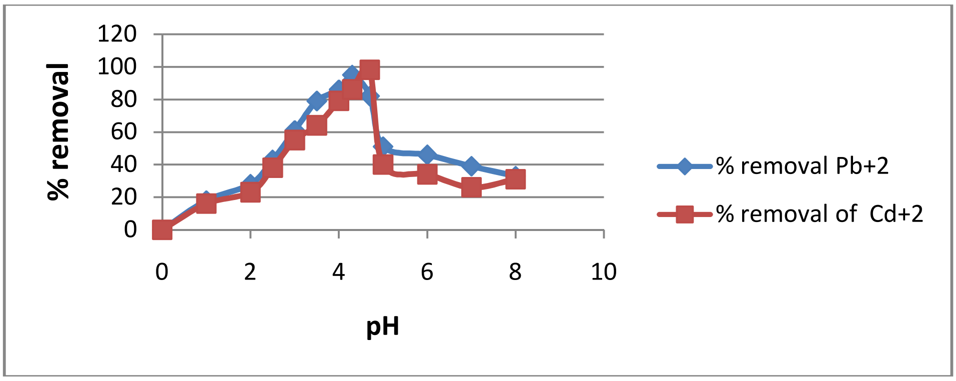

Fig.1

Effect of amount of biomass

It was important to fix the amount of the Jackfruit plant leaf powder to design the optimum treatment systems and for a quick response of the analysis. To achieve this aim, a series of batch experiments were conducted with the adsorbent dose of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 g per 100 ml of test solution. When the addition of the adsorbent dose increased, the percentage removal of metal ions also increased. A maximum removal of 95% of lead and 98% of cadmium, respectively, was obtained at 2.8 g of the Jackfruit plant leaf powder. It can be seen from Fig. 2 that an adsorbent dose of 2.8 g was sufficient for optimal removal of both metals in aqueous solutions. A further increase in the quantity of biomass dose did not have any significant effect on the removal of lead and cadmium ions from the solution.

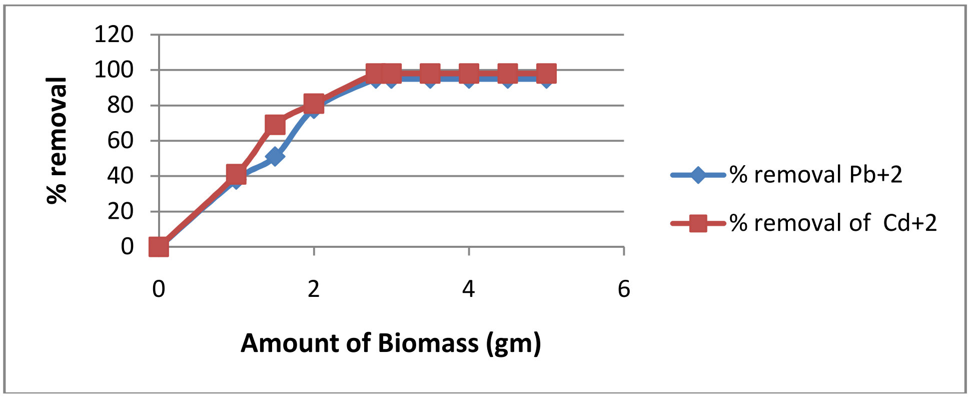

Fig.2

Effect of contact time

After optimization of the biomass dose at 2.8 g per 100 ml test solution and the pH at 4.3 for lead ion solution and 4.7 for cadmium ion solution, the effect of contact time for the efficient removal of metal ions was studied. The two metals showed a steady rate increase of Biosorption during the sorbate-sorbent contact process. The rate of metal removal was higher in the beginning due to a larger surface area of the adsorbent being available for the adsorption of the metals[13]. The rate of removal became almost insignificant due to a quick exhaustion of the adsorption sites. In these studies, 95% removal of lead and 98% removal of cadmium were achieved at 170 min. Further, no significant changes were observed in the removal of both metal ions from the solution after 24 h of equilibration (Fig. 3).

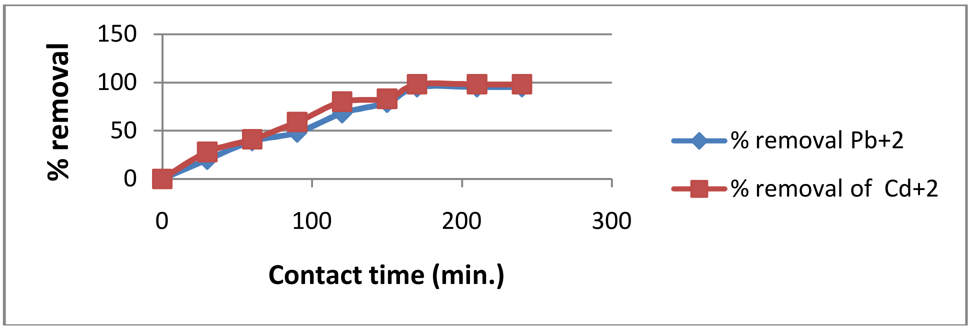

Fig.3

Effect of metal ions concentration

The metal uptake mechanism is particularly dependent on the heavy metal concentration. Initial concentrations of 50 and 100 mg/l of metal ions were selected for the comparative study for the removal of Pb(II) and Cd(II). Fig. 4 shows the effect of metal concentration on the removal of lead and cadmium ions. At the metal ion concentration of 50 mg/l and the optimum dose of 2.8 g of the biomass, the maximum removal of Pb(II) and Cd(II) was achieved within 90 min. However, at 100 mg/l, the maximum removal was only after 170 min. This observation clearly indicates that the removal of metal ions purely depend on the amount of adsorbent and contact time. The heavy metals were adsorbed by specific sites provided by the acidic functional groups on the biomass. With increasing metal concentration, the specific sites were saturated and the process of Biosorption became slow[14]. It indicated that with increasing initial concentrations, the metal removal decreases.

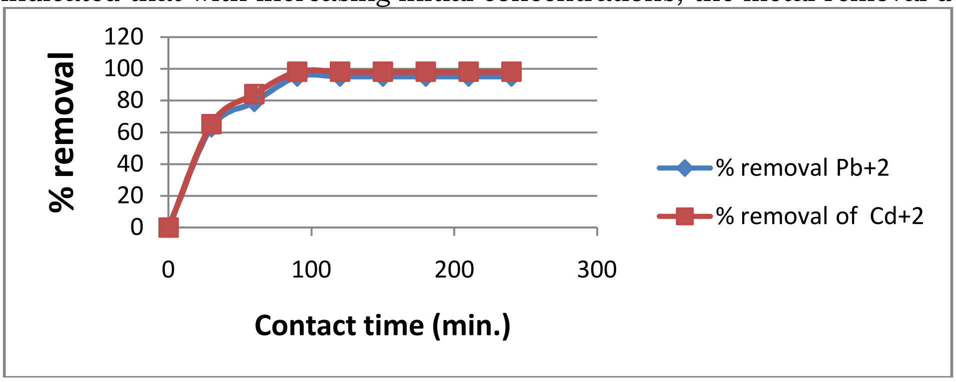

Fig.4

The following Table indicates the set parameters-

Table-1: Experimental Parameters

Parameter	Value
pH	Pb^{+2} = 4.3, Cd^{+2} = 4.7
Biomass dose	2.8 gm
Contact time	170 min.
Initial concentration	50mg/dm^3 or less

Recyclability of Biomass- Desorption study[15]

The natural material used in the present work was found to be reusable. The study indicated that the removal of adsorbed metal ions was possible in acidic medium and exact concentration of acid was found to be 0.1 M for both Pb^{+2} and $Cd.^{+2}$

Table-2: Study of % Desorption of metal ions

Initial metal Concentration	% Desorption					
	H_2O		HCl (0.05M)		HCl (0.1M)	
	Cd^{+2}	Pb^{+2}	Cd^{+2}	Pb^{+2}	Cd^{+2}	Pb^{+2}
50mg/dm^3	1.2	2.5	85.0	81.2	98.2	96.0

The following Table indicates data for recycling of adsorbent.

Table-3: Study of recycling of adsorbent

No. of runs	% Removal	
	Cd^{+2}	Pb^{+2}
1	93	91
2	90	87
3	88	84

The set parameters were applied to actual bore well water samples and results were as follows-

Table-4: Final set parameters

Metal ion	Initial concentration of sample	Final concentration	% removal
Pb^{+2}	1.1 mg/dm^3	0.055 mg/dm^3	95% (= 1.045 mg/dm^3)
Cd^{+2}	0.008 mg/dm^3	0.0003 mg/dm^3	97% (= 0.0077 mg/dm^3)

CONCLUSION

Removal of lead (II) and cadmium (II) from aqueous solutions was studied using Jackfruit plant leaf powder. Batch adsorption experiments were performed as a function of pH, contact time, solute concentration and adsorbent dose. The optimum pH required for maximum adsorption was found to be 4.3 and 4.7 for lead and cadmium, respectively. The maximum contact time for the equilibrium condition is 170 min at the sorbent dose rate of 2.8 g. The maximum efficiencies of lead and cadmium removal by biomass were 95% and 98%, respectively. Also, the selected biomass was found to be reusable and can be recycled for three turns without much loss of activity. When set conditions were applied to actual bore well water sample, 95% lead (II) and 97 % cadmium (II) could be removed.

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