Bio-sorption of heavy metal ions from aqueous solutions using dry biomass of canna indica

[*1] Gopkar NS, [2] Sahare AB, [3] Patil US

[1] Department of Botany, J. D. P. S. Mahavidyalaya, Daryapur, Dist. Amravati.

[2] Department of Chemistry, Science College, Paoni, Bhandara.

[3] Department of Botany, Bhartiya Mahavidyalaya, Amravati

Abstract

Increasing population and rapid industrialization increases effluent discharge into aquatic ecosystems. Heavy metals are major toxicants found in industrial effluents. Dried and powdered biomass of *Canna indica* including root, shoot and leaves has been used for the removal of Pb(II) metal ions from aqueous solution. The adsorption capacity of dry biomass was determined as a function of pH, contact time, initial concentration, doses of biomass & temperature. The results obtained shows that the pH has marked effect on metal ions uptake. The maximum adsorption observed at pH 6. After contact time of 80 minutes the percent removal of Pb(II) ion was 72.80, 80.45 and 93.75 on root, shoot and leaf respectively with initial concentration of 20mg/l. The effective dose of metal ion was 1g each of the root, shoot and leaf. The adsorption of Pb(II) was tested by Fruendlich adsorption isotherm and is inversely related to the temperature. Result shows that the leaves are more efficient media for removal of Pb(II) as compared to root & shoot. The study can be used for the development of an efficient, clean and cheap technology for effluent treatment.

Key Words: Lead removal, *Canna indica* plant, Adsorption, Fruendlich isotherm. Metal removal.

1. Introduction

The heavy metal make a significant contribution to environment as a result of human activities such as mining, energy & fuel production, smelting, electroplating, batteries and many more industrial activities. Some heavy metals like Fe, Zn, Mn, Cu, Mo and Ni are essential as micronutrient for animals & plants but some other heavy metal such as Pb, Cd, Hg, etc. at high concentrations has strong toxic effects [1]. These heavy metals are non-biodegradable pollutants and their presence in aquatic ecosystem leads to bioaccumulation in living organisms causing health problems in animals, plants and human beings.

Lead contamination of environment is primarily due to anthropogenic activities. It is the most common contaminant in urban soils due to atmospheric deposition & industries. The average lead content of igneous rocks is about 15ppm and hence it is categorized as rare element. Lead poisoning is well known for the extinct of Roman Empire. The toxic effects of Lead are mental retardation, brain damage, seizures, coma & finally death. The world health organization suggests a provisional tolerance of 7 µg/kg body weight per day for adults.

Many reports are available for removal of Pb(II) form water and wastewater using natural products and byproducts [2]. The present work deals with the study of removal of Pb(II) from aqueous solution using dry biomass of *Canna indica*. The root, shoot and leaf of the plant are selected for the study. The plant is found in India mostly in tropical regions. The plant parts can be easily processed and used for metal removal. So it may prove cost effective, green substance for water treatment.

2. Material and Methods

Preparation of biosorbent material from plant parts

The root, shoot and leaves of *Canna indica* were collected. First of all dried and finally powdered separately in an electric grinder. The grinded powder was sieved to obtain fine particles. The powdered biomass was washed several times with 0.1N HNO_3 and then with distilled water so that all the traces of acid was removed. Finally it is sun dried. Preliminary study was carried out using prepared adsorbent powder for the removal of Pb(II).

2.1 Preparation of Pb(II) ion solution

The 2000 mg/l stalk solutions of Pb(II) was prepared by dissolving required amounts of $PbNO_3$ in distilled water containing 0.1 ml conc. HNO_3 to prevent hydrolysis and diluted to 500 ml in a volumetric flasks. The stock solutions was diluted 100 times to obtain 20 mg/l Pb(II) solution in the 100 ml volumetric flasks. The pH of solutions was adjusted using dilute nitric acid and sodium hydroxide solutions. All the chemicals used were of analytical grade obtained from m/s E-merk.

2.2 Estimation of Pb(II) ions

The estimation of Pb(II) was carried out by Complexometric method. A known volume of Pb(II) solution was taken in a conical flask, its pH was adjusted to 10 using buffer solution and titrated against standard EDTA using EBT indicator.

2.3 Batch mode experiments

In order to study sorption potential of dry biomass of *Canna indica* for Pb(II) individually different concentration of metal ions (20-55 mg/l) was used. In addition the environmental conditions, such as pH (2-9) and temperature (30-90 °C) were also investigated to find out optimum pH and temperature for further equilibrium studies. The effect of contact time and doses of biomass was studied by taking different doses (1-4g) of prepared biomass for different interval of time (10-120 minutes) in 100 ml of 20 mg/l Pb(II) solution. The experiment has been carried out at 30ºC temperature. The samples were taken at shaking machine for 80 min agitation time. The solution was separated by using Whatmann No. 41 Filter paper and analyzed for Pb(II) content.

3. Result and Discussion

3.1 Effect of pH

The effect of pH is the key parameter in order to control the adsorption of metal ions on the adsorbent. Under acidic conditions the adsorption of Pb(II) in dry biomass was quite low (Fig. 1). There was an increase in Pb(II) adsorption with increase of pH from 2 to 6, beyond which there is no appreciable change in Pb(II) adsorption is observed. The results indicate that the optimum range for adsorption of Pb(II) by dry biomass of *Canna indica* was between 5-7. Normally pH of medium affects the solubility of metal ions and ionization state of the functional groups. The increase in biosorption of metal ions with increaseing pH indicates strong relation of biosorption to the number of surface active groups (functional groups). The low amount of metal ions is retained by biosorbent at low pH value below 4, because most of the functional groups are expected to dissociate only at neutral pH value. The competition between protons and metal ions for the same site is considerable at low pH values. The result also indicates that the leaf of the plant have more functional groups as compared to root and shoot.

3.2 Effect of Contact Time

The contact time is the necessary parameter to study the equilibrium process of adsorption. It is observed that increasing contact time more than 10 minutes has no appreciable effect on extent of adsorption of Pb(II) on dry biomass of *Canna indica*. The saturation level was obtained after 60 minutes, after this period the adsorbed Pb(II) ion did not significantly change further with time (Fig. 2). The adsorption of Pb(II) on dry biomass of *Canna indica* is reasonably fast. Hence, approximately 80 minute contact time was fixed in further studies.

3.3 Effect of initial metal ion concentration

The effect of The effect of initial metal concentration on Pb(II) removal by using dry biomass of *Canna indica* is shown in Fig. 3. The biosorbent dose, pH and contact time for the batch experiment were fixed at 10 g/L, pH 6 and 80 minutes respectively. Increasing the initial concentration of Pb(II) in a batch study resulted in decreasing percentage of Pb(II) removal because evidently the biosorbent was approaching its saturation uptake capacity. The adsorption sites are blocked as the metal ion concentration increased. In batch study using dry leaves percentage removal of Pb(II) decreased from 93 to 35% when the initial concentration of Ni was increased from 20 to 55 mg/l. The root and shoot showed a similar trend of decrease from 72 to 25% and 80 to 30% respectively in the similar conditions.

3.4 Effect of Biosorbent dose

The effect of adsorbent doses on removal of Pb(II) is shown Fig. 4. It is observed that the removal of Pb(II) ions increases with increasing adsorbent doses of biomass form 1 to 4g at fixed initial concentration of 20 mg/l. Higher doses of adsorbent increase the adsorption because adsorption sites remain unsaturated during adsorption reaction. The increased surface provides more possibilities for adsorption to occur since there is less competition for adsorption sites. Thus, the removal efficiency of Pb(II) reaches up to 99% on increasing adsorption dose for 1 to 4 g.

3.5 Effect of Temperatures

Temperature has marked effect on adsorption process. The Pb(II) ions adsorbed on the dry biomass at different temperatures 30, 50, 70 and 90 °C. The results are given in Fig. 5. It is observed that the metal ion removal decreases with increase in temperature.

3.6 Adsorption Isotherm

Two important physicochemical aspects of evaluation of the adsorption process as a unit operation are the equilibrium of the adsorption and the kinetics. Equilibrium studies give the capacity of the adsorbent. The equilibrium relationship between adsorbent and adsorbate are described by adsorption isotherms, usually the ratio between the quantity adsorbed and that remaining in solution at a fixed temperature at equilibrium. Most often Biosorption equilibria are described with adsorption isotherms of Langmuir or Freundlich types. The Fruendlich Adsorption Isotherm was tested for adsorption of Pb(II) on dry biomass of *Canna indica*. The values in the adsorption isotherm are summarized in Fig. 6.

The relative coefficient of this model was calculated using linear fitting as:

$$\log \frac{X}{M} = \log k_c + n \log C_e$$

The log X/M is plotted against log C_e;
Where, X/M is the concentration of metal ion adsorbed per g of tree bark and C_e is residual concentration of the metal ion. The plot is a straight line indicates that the adsorption of metal ion on dry biomass follow Freundlich equation. k_c and n are the sorption capacity (in mg/l) and intensity respectively. The value of n obtained from slope and that of k is intercept of the graph.
The applicability of isotherm was evaluated by the value of correlation regression (R^2). The model implies that the adsorption of Pb(II) was based on sorption on heterogeneous surface. It is confirmed by 1/n value which was between 0.1 and 1.0. The regression parameters for adsorption of Pb(II) are given below in Table 1. The linear correlation of adsorption isotherm indicates the multilayer adsorption takes place on the surface of bark and greater tendency of the metal to be adsorbed on the on the adsorbent surface [3].

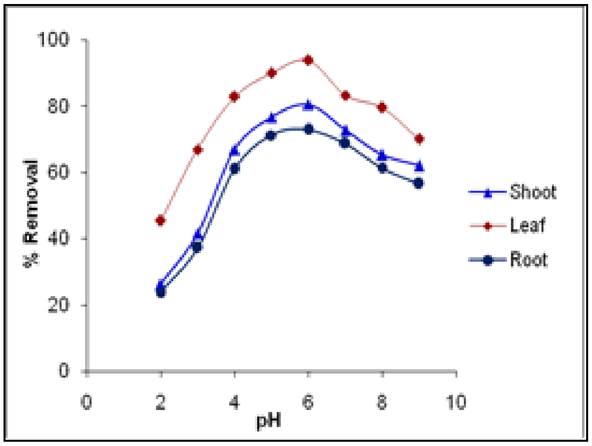

Fig 1: Effect of pH on adsorption of Pb(II)

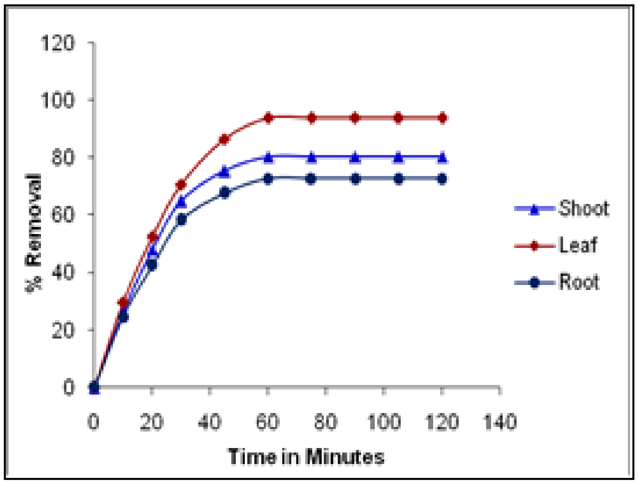

Fig 2: Effect of contact time on adsorption of Pb(II)

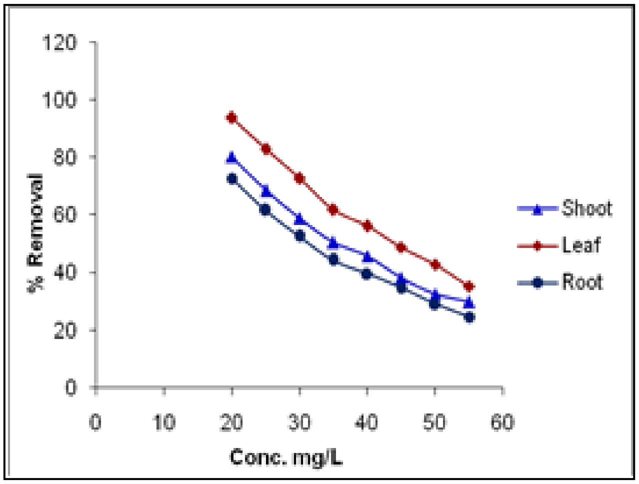

Fig 3: Effect of initial concentration on adsorption of Pb(II)

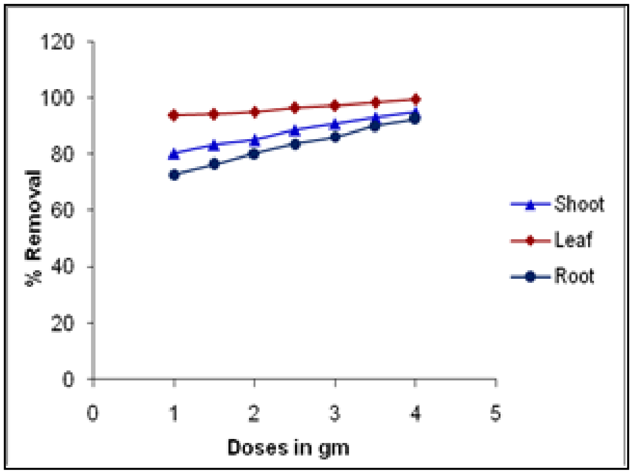

Fig 4: Effect of doses of tree bark on adsorption of Pb(II)

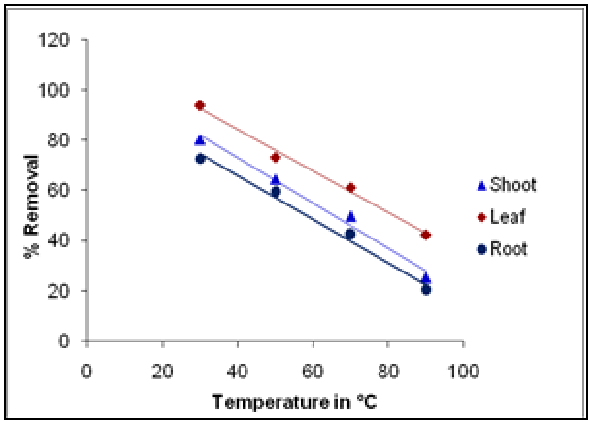

Fig 5: Effect of temperature on adsorption of Pb(II)

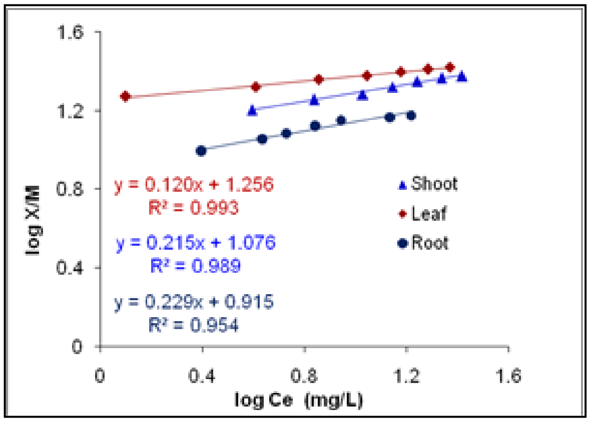

Fig 6: Fruendlich adsorption isotherm for adsorption of Pb(II)

Table 1: Regression parameters for adsorption isotherm

Plant Parts	R^2	R	log k_c	k_c	1/n	n
Root	0.954	0.977	0.915	8.222	4.367	0.229
Shoot	0.898	0.947	1.076	11.19	4.651	0.215
Leaf	0.993	0.996	1.256	18.03	8.333	0.120

3.7 Mechanism of Adsorption of Metal Ions

The adsorption behaviour of dry biomass is like a typical ion exchange resin with selectivity characteristics. Hence, it has different affinity for different metal ions. Like typical ion exchange, the metal ions in the solution exchange with the H+ ion resulting into decrease in pH of the metal ion solution. The fact also has been observed in present study where the final pH of metal ion solution is less than initial pH and the useful range of operation is limited by the H+ ion concentration. In fact the metal ions bounded to biomass can be completely leached back into solution by regenerating it with 0.01N mineral acid.

4. Conclusion

The dry biomass of *Canna indica* can be employed as an environmental friendly efficient media for the removal of Pb(II) ions from aqueous solution. The removal efficiency was clearly affected by pH of solution (the optimum pH range between 5-7), contact time (80 minute assigned), initial metal ion concentration and temperature. Biosorption equilibrium data for Pb(II) ions best fitted to Freundlich adsorption isotherm model indicating heterogeneous adsorption on the surface [4-5]. The adsorption process reaches equilibrium within 60 minutes at pH 6. Adsorption capacity is high despite the low surface area, indicating the availability of functional groups. These findings suggest that dry biomass of *Canna indica* is best adsorbent for removal of lead.

5. References

1. Rezaee AJ, Derayat SB, Mortazavi Y, Yamini, Jafarzadeh MT. Removal of Mercury from chlor-alkali Industry Wastewater using Acetobacter xylinum Cellulose, American Journal of Environmental Sciences 2005; 1(2):102-105.
2. Pappalardo L, Jumean F, Abdo N. Removal of Cadmium, Copper, Lead and Nickel from Aqueous Solution by White, Yellow and Red United Arab Emirates Sand. American Journal of Environmental Sciences 2010; 6(1):41-44.
3. Rafeah Wahi, Zainab Ngaini, Veronica Usun Jok. Removal of Mercury, Lead and Copper from Aqueous Solution by Activated Carbon of Palm Oil Empty Fruit Bunch. World Applied Sciences Journal. 2009; 5:84-91
4. Rozaini CA, Jain K, Oo CW. Optimization of Nickel and Copper Ions Removal by Modified Mangrove Barks, International Journal of Chemical Engineering and Applications, 2010; 1(1):84-89
5. Saifuddin N, Raziah AZ. Removal of Heavy Metals from Industrial Effluent Using Saccharomyces Cervisiae (Baker's Yeast) Immobilised in Chitosan/lignosulphonate Matrix, Journal of Applied Sciences Research, 2007; 3(12):2091-2099