Research Article
ISSN: 2456-8473
International Journal of Chemistry, Pharmacy & Technology
Vol. 2, No.6, pp-240-246, 2017

THE EFFECT OF SOME PHYSICOCHEMICAL PARAMETERS ON THE BIOREMEDIATION OF CADMIUM (Cd^{2+}) FROM AQUEOUS SOLUTION USING *ADANSONIA DIGITATA* L. SEED CAKE RESIDUE AS BIOSORBENT

P.R.O. Edogbanya[1]*, M.A. Adelanwa[1], D.S. Abolude[1] and O.J. Ocholi [2]
[1]Department of Biological Sciences, Faculty of Science, Ahmadu Bello University, Zaria, Nigeria.
[2]Department of Chemistry, Faculty of Sciences, Ahmadu Bello University, Zaria, Nigeria.
Corresponding Author: ocholiedogbanya@gmail.com
Received 12-05-17; Revised & Accepted: 15-06-17

ABSTRACT

In this study, the effect of some physicochemical parameters on the bioremediation of cadmium (cd^{2+}) from aqueous solution using *Adansonia digitata* l. seed cake residue as biosorbent was evaluated. Dried fruits of *Adansonia digitata* L. were collected from the Department of Biological Sciences, Ahmadu Bello University, Zaria. The seeds were excised, washed with sterile distilled water, sun dried, powdered and defatted using n-hexane to give *Adansonia digitata* cake residue (ADCR) which was used as the biosorbent. Standard stock solution (30 mg/L) of Cadmium Nitrate $Cd(NO_3)_2$ was prepared by weighing 30mg of the salt and dissolving in 1L of deionized water this was further diluted for further study. Batch experiments were carried out to study the effect of pH, initial concentration of metal salts, dosage of biosorbent, and contact time. The experimental design was Cross Randomized Design (CRD) and One way Analysis of Variance (ANOVA) was used to determine significant difference among means of the various parameters measured. Duncan Multiple Range Test (DMRT) was used in separating means with different significant values. The level of significance was taken at $p < 0.05$. The results revealed that the biosorption efficiency increased significantly ($p < 0.05$) as pH increased from 2 – 10, initial concentration of metal salt increased from 5 - 30 mg/L, dosage of biosorbent increased from 50 - 200mg/L, and as contact time increased from 5 - 60 min. A maximum biosorption efficiency of 74.25% was observed at a dose of 200mg/L ADCR, initial concentration of metal ion of 30mg/L, pH of 7, and contact time of 60min. From this study *Adansonia digitata* L. seed could be considered as a potential, eco-friendly, low cost, biosorbent for the removal of Cd^{2+} from aqueous solution.

Keywords: *Adansonia digitata* L., Bioremediation, Biosorbent, Cadmium, Seed, Water

INTRODUCTION

Water is an indispensable resource in the sustenance of life on earth. Its importance to man crosses various facets of life including domestic, agriculture, industrial, commercial, economic, and social to mention just a few. Its availability is tied to the overall well-being of man and sustainable development. Unfortunately man through adverse practices has contributed to the increasing pollution of water in his environment, which in turn has led to the reduction in the quantity and quality of water available to him [1].

As at 2015, 663 million people still lack improved drinking water sources a majority of which dwell in rural areas. It is estimated that 79% of people using unimproved sources and 93% of people using surface water live in rural areas. Significant proportions of the population in sub-Saharan Africa and Oceania continue to use rivers, lakes, ponds and irrigation canals as their main source of drinking water [2].

Heavy metals are known to be one of the most fatal pollutants of water. This is because they are very poisonous even in very minute quantities in water [3,4,5]. They find their way into surrounding water bodies majorly as a result of adverse activities carried out by man such as: discharge of untreated industrial wastes into water bodies; improper use of agro-allied chemicals such as pesticides, herbicides and fertilizers; mining activities [6].

Cadmium is one of the most common heavy metals that could be found in water. Fertilizers produced from phosphate ores constitute a major source of diffuse cadmium pollution. The estimated lethal oral dose of cadmium for humans is 350 – 3500 mg. Cadmium in drinking water has a number of adverse effect on humans, amongst which kidney dysfunction and osteoporosis are the most common [7].

A number of conventional methods have been developed to remove heavy metals such as cadmium from water. They include: ion exchange [8], Coagulation [9], flotation [10], Co-precipitation [11], Solvent extraction [12], membrane technology [13,14], adsorption [15]. These methods are relatively expensive and therefore there is a need for cost effective alternative technologies for the removal of heavy metals from water such as biosorption.

Biosorption is a promising technique that involves the use of less expensive natural materials (especially of plant origin – many of which are agricultural wastes) that can be easily obtained from the environment. A number of researches have been carried out on biosorbents and many have been reported to have high uptake capacity. Due to these properties biosorption is progressing toward a sustainable method and warrants further research to consolidate on the progress that has already been made [16].

In the present study *Adansonia digitata* L. seed was used as a biosorbent for the removal of cadmium from model polluted water. *Adansonia digitata* L. is a deciduous tree that belongs to the Malvaceae family. It possesses large pendulous shaped fruits that contain many seeds. It is a long lived tree with multipurpose uses [17].

MATERIALS AND METHODS

Collection, verification, and preparation of plant material

Dried fruits of *Adansonia digitata* L. used for the study were collected from a single tree in the Botanical Garden of the Department of Biological Sciences, Ahmadu Bello University, Zaria, and were taken to the herbarium of the Department for verification and confirmation. It was allocated a herbarium voucher number of 2512. The fruits were split open, seeds were mechanically removed, properly washed with distilled water, sun dried, pulverized into powder using mortar and pestle, sieved through a pore size of about 1mm, and stored in airtight containers for further usage.

Preparation of *Adansonia digitata* cake residue (ADCR)

The powdered seed sample was de-fatted using n-hexane in electro-thermal Soxhlet extractor (Gallenkamp, England). 30g of powdered seed was weighed and put into the thimble of the Soxhlet extractor, the apparatus was mounted and allowed to run for an hour, after which the powder was removed and dried over a hot plate at low heat (to evaporate the excess n-hexane) to give *Adansonia digitata* cake residue (ADCR). This was then used as the biosorbent for further study.

Preparation of stock solution of heavy metal

All chemicals that were used was of analytical grade. Standard stock solution of $Cd(NO_3)_2$ salt was prepared by weighing 30mg of the salt and dissolving in 1L of deionized water [15]. Further dilutions were made from the stock solutions for the study.

Batch adsorption experiments

Batch adsorption experiments were carried out to study the effect of pH (pH was varied from 2 - 10 using HCl and NaOH), initial concentration of metal salt (5, 10, 20, 30 mg/L), dosage of biosorbent (50mg/L, 100mg/L, 150mg/L and 200mg/L), and contact time (5, 15, 30, 60 min) on adsorption, by varying the parameter of concern and making all others constant. In all the experiments 100ml of metal solution of known concentration was taken in polyethylene bottles along with the required amount of biosorbent (de-fatted powdered *Adansonia digitata*). The bottles were covered properly and agitated at a 120rpm with a laboratory shaker (Gallenkamp England) for a particular period of time corresponding to the desired contact time to achieve equilibrium. After agitation the mixture was passed through filter papers (Whattman No. 1) and stored in polyethylene sample bottles. The residue concentration of Cd^{2+} in solution was determined using Atomic Absorption Spectrophotometer (AA 240 FS Varian).The experiments were carried out in triplicates with their respective controls [18,19].

The removal efficiency R_e (%) of heavy metal ions was calculated using equation 2:

$$R_e = \frac{(C_o - C_e)}{C_o} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

The Adsorption studies was carried out in the multiusers laboratory of the Department of Chemistry, Ahmadu Bello University, Zaria.

Statistical Analysis

The experimental design used was Complete Randomized Design (CRD). ANOVA (Analysis of Variance) was used to compare the mean removal efficiency of Cd^{2+} for the different groups of treatment, and DMRT (New Duncan Multiple Range Test) was used to separate means where there was significance. In the kinetic studies of adsorption, regression analysis was used to examine the relationship between the amount of heavy metal ions adsorbed per unit mass of the biosorbent and the contact time. The confidence level of was taken at 95% ($p < 0.05$). SPSS software (version 20.0) was used to run the analysis.

RESULTS AND DISCUSSION

ADCR was able to adsorb the metal ions Cd^{2+} from aqueous solution. Variation of various parameters (pH, initial concentration of metal ions, dosage of biosorbent, and contact time) had significant effects ($p < 0.05$) on the biosorption efficiency of the biosorbent. Biosorption for agricultural by-products like the residual seed cake of defatted *Adansonia digitata* seeds(ADCR), have been attributed to two main terms; coulombic interaction and intrinsic adsorption [20]. The coulombic term results from the electrostatic energy of interactions between the adsorbents (biosorbent) and adsorbates (metal ion solution). The strength of charges on biosorbent and biosorbate are mostly responsible for the intensity of the interaction [20].

The intrinsic adsorption is due to the nature of the surface area of biosorbent. For instance it has been observed that different particle sizes of a particular biosorbent have different effect on its adsorption capacity.

Effect of contact time on biosorption efficiency

As the contact time of ADCR with metal solution was increased from 5 – 60 min, while the other parameters were kept constant (dose of ADCR at 200mg/L; initial concentration of metal ion at 30mg/L; pH of 7; and rotation speed of 120rpm) the biosorption efficiency increased significantly ($p < 0.05$). A maximum biosorption efficiency of 74.25% was observed at a contact time of 60min (Fig 1). It was observed that the biosorption of Cd^{2+} took place in two distinct phases: a rapid phase which took place within 5 minutes and a slow phase that took until 60 minutes. The rapid biosorption was probably due to the initial availability of many binding sites and as the binding sites became exhausted biosorption took place at a slower rate [21].

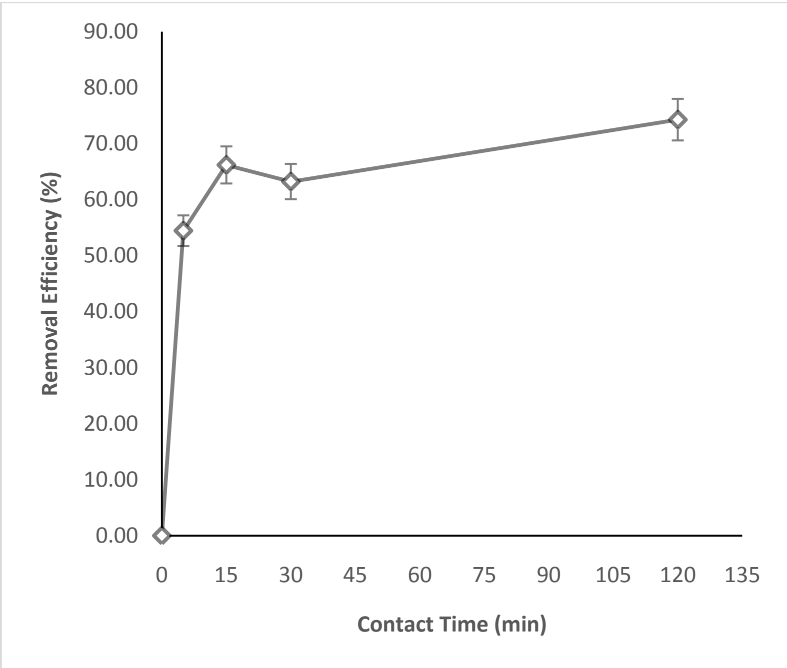

Fig 1 Effect of contact time on the biosorption efficiency of ADCR for $Pb2^{+}$
dosage of ADCR = 200mg/L, initial concentration of metal ion =30mg/L, pH = 7, rotation speed = 120rpm

Effect of dosage of biosorbent (ADCR) on biosorption efficiency

As the dose of biosorbent was increased from 50mg/L – 200mg/L, while other parameters were kept constant (initial concentration of metal ion at 30mg/L; pH of 7; contact time of 30min and rotation speed of 120rpm), the biosorption efficiency also increased significantly ($p < 0.05$). A maximum biosorption efficiency of 72.98% was observed at a dose of 200mg/L (Fig 2). This is probably due to the fact that an increase in dosage makes available more binding sites for the metal ions, hence an increase in the efficiency of their removal from solution [21].

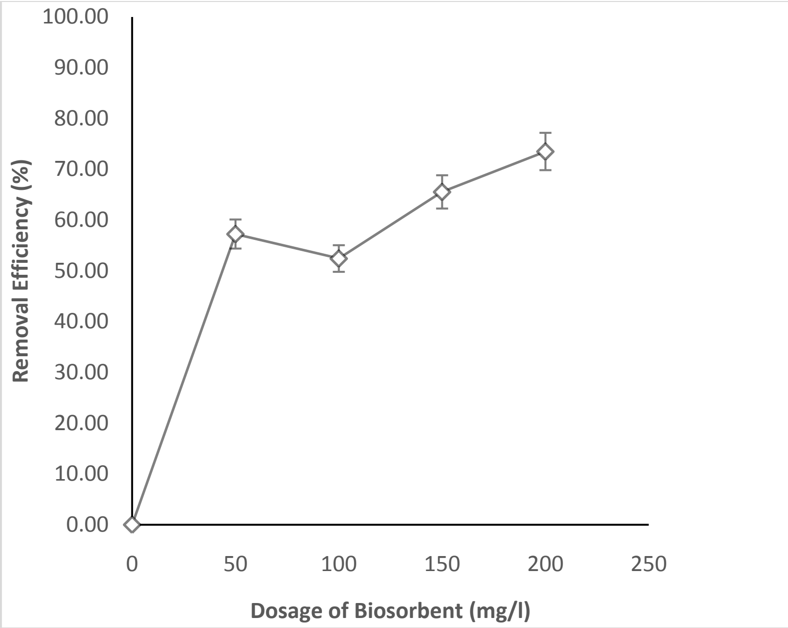

Fig 2 Effect of dosage on biosorption efficiency of ADCR for Cd^{2+}
initial concentration of metal = 30mg/L, pH = 7, contact time = 30min, rotation speed of 120 rpm

Effect of pH on biosorption efficiency

As the pH was adjusted from 2 – 10, while other parameters remained constant (initial concentration of metal ion at 30mg/L; dosage of ADCR at 200mg/L; contact time of 30min and rotation speed of 120rpm), the biosorption efficiency of the biosorbent increased significantly ($p < 0.05$). A biosorption efficiency of 74.19% was obtained at pH 10 (Fig 3). At a lower pH (acidic) the hydrogen ions (H^+) from the acid make the overall surface of the biosorbent to be positively charge and this leads to the repelling of the metal ions and hence a reduction in the biosorption efficiency of the biosorbent. At higher pH (basic) the hydroxide ions (OH^-) introduced by the base causes the overall surface of the biosorbent to be negatively charge leading to the attraction of more metal and hence an increase in the biosorption efficiency of the biosorbent [22].

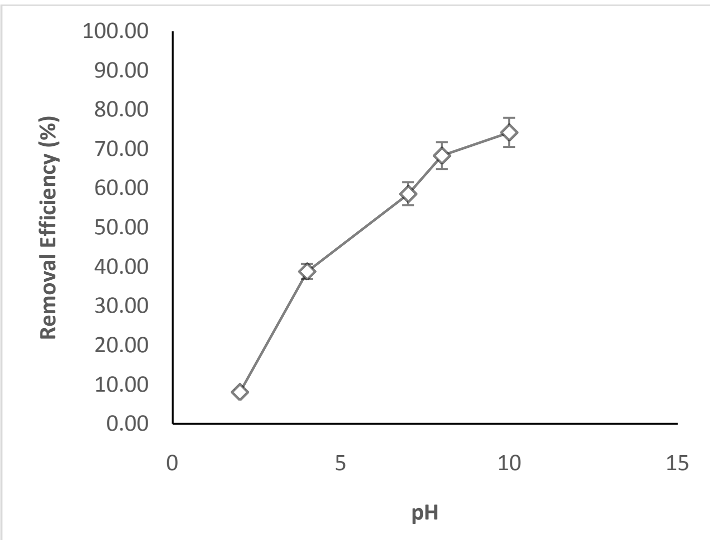

Fig 3 Effect of pH on the biosorption efficiency of ADCR for Cd^{2+}
initial concentration of metal ion = 30mg/L, dosage of ADCR = 200mg/L, contact time = 30min, rotation speed = 120rpm

Effect of initial concentration of Cd^{2+} on biosorption of efficiency

As the initial concentration of Cd^{2+} ion was increased from 0 – 30mg/L, while other parameters were kept constant (Dosage of ADCR at 200mg/L; contact time of 30min; pH 7 and rotation speed of 120rpm) the biosorption efficiency also increased significantly ($p < 0.05$). A biosorption efficiency of 61.59% was observed at an initial concentration of 30mg/L (Fig 4). The increase in biosorption efficiency may be due to an increase in the concentration gradient as initial concentration of ions increased which served as a driving force [23].

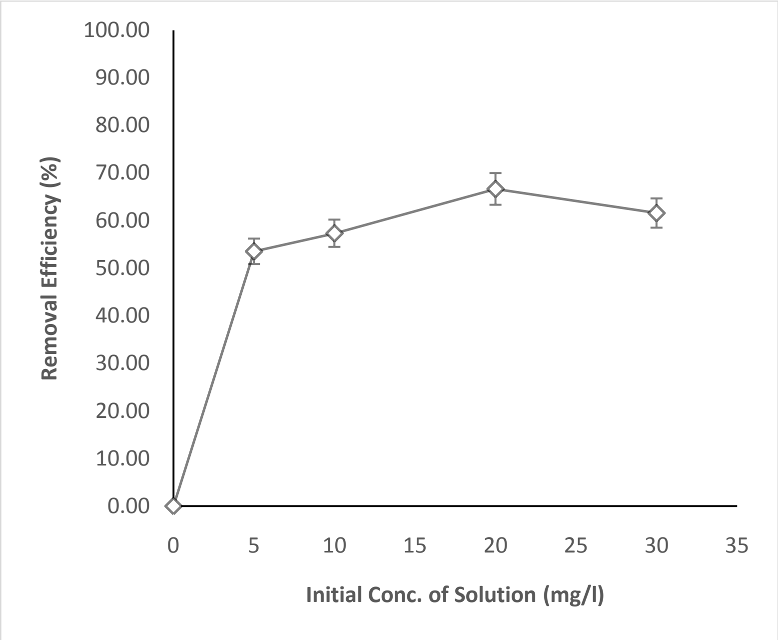

Fig 4 Effect of initial concentration of Cd^{2+} on the biosorption efficiency of ADCR dosage of ADCR at 200mg/L, contact time of 30min, pH 7, rotation speed = 120rpm

CONCLUSION

From the research it can be concluded that ADCR may serve as a potential, eco-friendly, low cost, biosorbent for the removal of Cd^{2+} from aqueous solution. With chemical or physical modifications of the nature of ADCR (such as conversion to activated carbon) its biosorption capacity may be improved and adapted for large scale use.

REFERENCES

1. WWAP (United Nations World Water Assessment Programme), The United Nations World Water Development Report 2015: Water for a Sustainable World. Paris, UNESCO, 2015.
2. WHO and UNICEF, Progress on Sanitation and Drinking Water – 2015 update and MDG assessment. Geneva: WHO Press, 2015, 1 – 80.
3. Igwe J.C. and Abia A.A., A bioseparation process for removing heavy metals from waste water using biosorbents. African Journal of Biotechnology, 2006, 5 (12), 1167-1179.
4. Mudgal V., Madaan N., Mudgal A, Singh RB and Mishra S., Effect of toxic metals on human health. The Open Nutraceuticals Journal, 2010, 3:94-99.
5. Edogbanya P.R.O., Ocholi O.J. and Apeji Y., A review on the use of plants' seeds as biosorbents in the removal of heavy metals from water. Advances in Agriculture, Science and Engineering Research, 2013, 3 (8), 1036-1044.
6. Celik A., and Demirbas A., Removal of heavy metal ions from aqueous solutions via adsorption onto modified lignin from pulping wastes, Energy Sources, 2005, 27, 1167-1177.

7. WHO, Lead in Drinking-waterBackground document for development of WHO Guidelines for Drinking-water Quality. Geneva: WHO Press, 2011, 1 – 19.
8. Wang W., Fthenakis V., Kinetics study on separation of cadmium from tellurium in acidic solution media using ion-exchange resins. Journal of Hazardrous Materials ,2005, 125:80-88.
9. Nakajima J., Fujinami M. and Oguma K.A., Novel separation and preconcentration method for traces manganese, cobalt, zinc and cadmium using coagulation of colloidal silica, Analytical Science,2004, 20, 1733-1736.
10. Ghazy SE and Mostafa GA (2008) Separation of cadmium (II), mercury (II), bismuth (III) and antimony (III) from drinking and river waters by flotation, Canad. J. Anal. Sci. Spectro. 53:28-35.
11. Inagaki K., Takatsu A., Uchiumi A., Nakama A. and Okamoto K., Determination of cadmium in sediment by isotope dilution inductively coupled plasma mass spectrometry using a co-precipitation separation technique, Journal of Analytical Atomic Spectrometry, 2001, 16, 1370–1374.
12. Mane C. P., Analytical applications of 2-octylaminopyridine. Dissertation, Shivaji University, Kolhapur, India, 2008.
13. Urtiaga A.M., Alonso A., Ortiz I., Daoud J.A., El-Reefy S.A., Pérez S., de Ortiz. and Gallego T., Comparison of liquid membrane processes for the removal of cadmium from wet phosphoric acid, Journal of Membrane Science, 2000, 164, 229-240.
14. Bansal B., Mahajan R., Hossain M. and Liaw M.S., Application of liquid membrane to recover cadmium, Development of Chemical Engineering Mineral Process, 2006, 14, 227-238.
15. Sen T.K., Agricultural by-product biomass for removal of pollutants from aqueous solution by adsorption, Journal of Environmental Resources and Development, 2012, 6 (3), 524-533.
16. Igwe J.C. and Abia A.A., Maize cob and husk as adsorbents for removal of Cd, Pb and Zn ions from wastewater. The physical Science, 2003, 2, 83-94.
17. Sidibe M. and Williams J.T., Baobab – Adansonia digitata. Fruits for the future. International Centre for Underutilised Crops, Southampton, UK, 2002, 96p.
18. Njoku V.O., Ayuk A.A., Ejike, E.E., Oguzie E.E., Duru C.E. and Bello O.S., Cocoa pod husk as a low cost biosorbent for the removal of Pb(II) and Cu(II) from Aqueous solutions. Australian Journal of Basic and Applied Sciences, 2011, 5 (8), 101-110.
19. Alam M., Nadeem R., and Jilani, M.I., Pb (II) removal from wastewater using Pomegranate waste biomass. International Journal of Chemical and Biochemical Sciences, 2012, 1, 24-29.
20. Gang S. and Weixing S., Sunflower stalks as Adsorbents for the removal of metal ions from wastewater. Indian Engineering Chemistry Research, 1998, 37, 1324-1328.
21. Aravind J., Muthusamy S., Sunderraj., S.H, Chandran L. and Palanisamy K., Pigeon pea (Cajanus cajan) pod as a novel eco-friendly biosorbent: a study on equilibrium and kinetics of Ni(II) biosorption. International Journal of Industrial Chemistry, 2013, 4 (25), 1 - 9
22. Kumari P., Sharma P., Shalini S. and Srivastava M.M., Biosorption studies on shelled Moringa oleifera Lamarck seed powder: removal and recovery of arsenic from aqueous system, International Journal of Mineral Processes, 2006, 78, 131- 139.
23. Han R., Zhang J., Zou W., Xiao H., Shi J. and Liu H., Biosorption of copper (II) and lead (II) from aqueous solution by chaff in a fixed-bed column. Journal of Hazardous Materials, 2006, 133, 262-268.