Removal of Cadmium [Cd (II)] ion by Activated Carbon Prepared from Eichhornia Crassipes Mart (ACECM)

Pramod Kumar Singh[*1] & Lalji Verma[2]

1&2. Environment Science Division, Department of Chemistry, School of Applied Sciences, Babu Banarasi Das University Lucknow-226028(U.P.), India.
e-mail: singh_p_kumar@rediffmail.com[1], lalji40@gmail.com[2]

Publication Info

Article history :

Received : 16th Nov. 2017

Accepted : 06th Dec. 2017

DOI : /10.18090/samriddhi.v9i02.10871

Keywords: *Domestic wastewater, adsorption, cadmium, activated carbon, carbonization.*

***Corresponding author :**

Pramod Kumar Singh

e-mail : singh_p_kumar@rediffmail.com

Abstract

Cadmium is the most toxic heavy metal which is now entering food chain by water. Cadmium and its compounds are, compared to other heavy metals, relatively water soluble. They are therefore also more mobile in soil, generally more bio-available and tend to bioaccumulation. Removal of cadmium [Cd (II)] from aqueous solutions using activated carbon prepared from Eichhornia crassipes Mart. (ACECM), a perennial aquatic plant (or hydrophyte) was studied. The adsorbent made from different part (root, petiole and leaf) of water hyacinth were used to remove of the Cd (II) from domestic wastewater. The influence of various parameters such as effect of pH, agitation speed, adsorbent dose, contact time, and initial concentration of metal ions and on the removal Cd (II) was evaluated. Results indicated that maximum removal efficiency (76.58%) of Cd (II) at pH values 4.0 for all part i.e., root, petiole and leaf while the maximum adsorption capacity (70%) of ACECM for metal ion was 2 g l^{-1} in all parts. 70% removal efficiency was observed at 45 rpm agitation speed in all parts while contact time was non-significant.

1. INTRODUCTION

Contamination of various natural resources including water by heavy metals is a great concern now a days. Cadmium is generally considered to be one of the most toxic metals found in the environment. Mining and metallurgy of cadmium, cadmium electroplating, battery and accumulator manufacturing, pigments, ceramics, textile printing industry wastewaters and lead mine drainage [1, 2], but also sewage sludge [3] contain various amounts of Cd (II) ions. The main treatment processes for the removal of Cd(II) ions from waste streams include its precipitation as hydroxide [1, 4] and carbonate [5], evaporation, adsorption, ion exchange, membrane processing, solvent extraction etc. [2]. Adsorption and ion exchange processes have significant benefits-the treated water is often sufficiently pure to be recycled and reused and adsorbed metals can be often recovered and purified in well-designed regeneration processes [6]. Activated carbon is the most widely studied adsorbent for the removal of Cd (II) ions from aqueous solution. Since activated carbon production is too expensive for large-scale use, various alternative sources have been used in its production. Therefore many studies have been focused on preparation of activated carbons from cheaper and readily available materials such as coir pith [7], coco-nut tree saw dust [8], almond shells, olive and peach stones [9], oil palm stones [10] and plum kernels [11]. Other agricultural wastes such as sugarcane bagasse [12], nut shells [13], black gram husk [14], maize cob husk[15], walnut, hazelnut, almond, pistachio shell, and apricot stone[16] and their application for the removal of lead, zinc, copper, and Cd(II) from water and waste water in-spite of several researchers adopted various low cost adsorbents for the removal metal ions from aqueous solution.

Activated carbon adsorption appears to be a particularly competitive and effective process for the removal of toxic heavy metals. The adsorption capacity of an adsorbent is determined by its pore size, chemical structure that influences its interaction with polar and nonpolar adsorbents, and active sites which determine the type of chemical reactions with other molecules [13]. However, commercial activated carbon (CAC) remains an expensive material for heavy metal removal. The use of local, natural and cheap materials that are available in large quantities or certain waste from agricultural operations for treatment of water and waste water containing heavy metals in developing countries is an area that is gaining interest.

Eichhornia crassipes Mart. is a free-floating perennial aquatic plant (or hydrophyte) native to tropical and sub-tropical South America. One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolon's, which eventually form daughter plants. It was introduced in Bengal in India because of its beautiful flowers and shapes of leaves, but turned out to be an invasive weed draining oxygen from the water bodies and resulted in death of many fishes. Fish is a supplement food in Bengal, and because of the fish scarcity in Bengal caused by *Eichhornia*, the water hyacinth is also called "Terror of Bengal".

The adsorbent made from different part (root, petiole and leaf) of water hyacinth were used to remove of the Cd (II) from domestic wastewater. The objective of this study was to investigate whether activated carbon prepared from *Eichhornia crassipes* Mart. (ACECM) could be used as an alternative for commercial activated carbon for the removal of Cd (II) from domestic wastewater. The influence of various parameters such as pH, initial concentration of metal ion, contact time, and adsorbent dose on the removal efficiency of the ACECM was studied.

2. MATERIAL AND METHODS

2.1 *Procedure of Adsorbent Preparation and Activation*

Eichhornia crassipes Mart. collected from the river Gomti. The preparation and activation of the carbon prepared from *Eichhornia crassipes* Mart. was performed by the following procedure. The collected water hyacinth was washed many times to remove the mud and other organic matter which are present. Washed water hyacinth was weighted on the weight machine and then make the different part of the plants like root zone, petiole and leaf which were used to prepare activated carbon of root (ACR), activated carbon of petiole (ACP) and activated carbon of leaf (ACL). It was dried at 95^{0}C till total moisture content have been removed and then taken dry weight. Activated carbon were prepared in different batch in absence of oxygen for 4hr in muffle furnace at 35^{0}C. The dried sample was sieved to pass through a 100-mesh sieve and stored in a desiccator for further use (fig.1).

Fig.1: Preparation of activated carbon from Eichhornia crassipes Mart. and its adsorption of Cd (II) ions from waste water.

- **Adsorption Processes :**

It is believed that the carbonization / activation step proceeds simultaneously with the chemical activation. Chemical activation is preferred over physical activation owing to the lower temperatures and shorter time needed for activating material.

- **Physical Reactivation :**

By this process precursor is developed into activated carbons using gases. This is generally done by using one or a combination of the following processes:

- **Carbonization :**

Material having appreciable carbon content is pyrolyzed at temperature ranging between 600–900 °C, in the absence of oxygen (usually in inert atmosphere with gases like argon or nitrogen)

- **Activation/Oxidation :**

In this process raw material or carbonized material is exposed to oxidizing atmospheres (carbon monoxide, oxygen, or steam) at temperatures above 250 °C, usually in the temperature range of 600–1200 °C.

- **Chemical Activation:**

Before carbonization, the raw material can be impregnated with certain chemicals. The chemical needs to be typically an acid, strong base, or a salt (phosphoric acid, potassium hydroxide, sodium hydroxide, zinc chloride, respectively). After impregnation, the raw material needs to be carbonized at 450–900 °C.

Adsorption experiments were conducted at different variables to study the best removal condition *i.e.*, contact time, temperature, agitation speed, pH, dose of adsorbent, initial concentration. Affecting variables of adsorption were mentioned in table 1.

Table-1: Different variables affecting adsorption of ACECM

Parameters	Variables	Constants
Contact time Range (0.5-5 hours)	Contact time	Temperature Agitation speed pH Dose of adsorbent Initial concentration
Agitation speed Range (25-60 rpm)	Agitation speed	Contact time pH Dose of adsorbent Temperature Initial concentration
Dose range (1-5 g l^{-1})	Dose	Temperature Agitation speed pH Contact time Initial concentration
pH range (1-10)	pH	Temperature Agitation speed Contact time Agitation speed Initial concentration
Effect of Initial concentration Constant	Concentration	Temperature Agitation speed Contact time Agitation speed pH

The aqueous phase was separated from activated carbon by centrifugation at 5000 rpm for 10 minutes and the concentration of residual Cd (II) ions in the supernatants was determined by atomic absorption spectrophotometer (Perkin Elmer 370 model). The amount of adsorbed Cd (II) ions was calculated by the difference of initial and final concentration.

3. RESULTS AND DISCUSSION

The absorption efficiency of the activated carbon which are made by water hyacinth having different in different conditions which were given below:

3.1 Effect of pH on Cd(II) ion adsorption

The pH of the solution affects the surface charge of adsorbent, the degree of ionisation and the speciation of the surface function groups [17]. For that reason, in many studies carried out to remove heavy metals from aqueous solutions, it has been pointed out that the pH of the solution is one of the most important parameters affecting adsorption yield. The effect of initial pH on the adsorption of Cd(II) ions was studied in present studied indicated that the value pH varied from 1 to 10 in Fig. 2. The removal percentage of Cd (II) ions was observed that adsorption was sharply increased upto pH 4 and it was tend to decreased sharply with increase in pH (Fig.2).

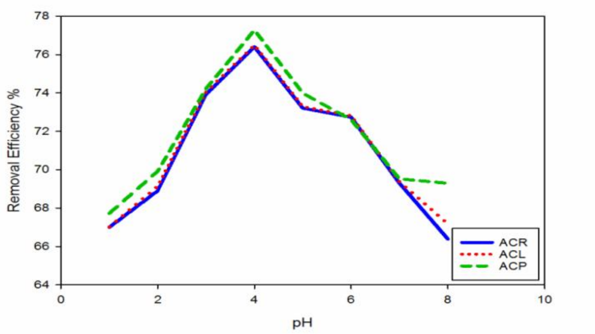

Fig.2: Effect of pH on adsorption Cd (II) by ACECM

The maximum removal percentages were found to be 77 % at pH 4. The optimum pH for Cd (II) ions adsorption from aqueous solutions by activated carbons from almond shells, olive and peach stone has been reported as 5.0 [10]. In other studies carried out with activated carbon from coirpith, maximum removal was attained at pH 4.0 [8]. Optimum pH for adsorption of Cd (II) ions by activated carbon from bagasse was reported as 4.5 [19]. Cimino et al. [20] have reported that maximum removal in the adsorption of Cd(II) ions by carbon from hazelnut shell treated with sulphuric acid was observed in the pH range from 4.0 to 6.0. In our previous study [18] related to Cd(II) ions adsorption, optimum pH has been found to be 6.3. These results show that the adsorption yield of Cd(II) ions by various adsorbents is dependent on pH of solution.

3.2 Effect of agitation speed on Cd(II) ion adsorption

Results indicated that agitation speed vary from 25-60 rpm at atmospheric temperature in which removal efficiency were observed 30-65% but best removal efficiency (65%) observed in root of ACECM at 45 rpm (fig. 3). Best removal efficiency were in all parts i.e., root, stem and petiole at 45 rpm. The 45 rpm is the best agitation speed for the removal of the cadmium form the sewage wastewater.

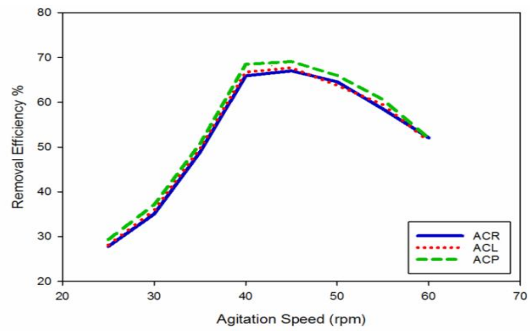

Fig.3: Effect of agitation speed on adsorption Cd (II) by ACECM.

3.3 Effect of Dosage on Cd(II) ion adsorption

Dosage study is an important parameter in adsorption studies because it determines the capacity of adsorbent for a given initial concentration of metal ion solution. The effect of adsorbent dose on the present removal of Cd(II) at initial concentration of 1 g l^{-1} is shown in Fig. 5. From the figure it can be observed that increasing of adsorbent dose initially increased the present removal of Cd (II) up to 65.5% with the required optimum dosage of 2 g.

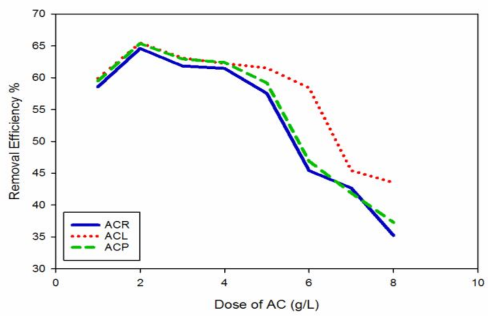

Fig.4: Effect of dose of activated carbon on adsorption Cd (II) by ACECM.

Beyond the optimum dosage the removal efficiency decreased with the adsorbent dose. As expected, the removal efficiency increased with increasing the adsorbent dose for a given initial metal concentration, because for a fixed initial adsorbate concentration increasing adsorbent dose provides greater surface area or more adsorption sites. Further, it can be attributed to the binding of metal ions onto the surface functional groups present on the ACECM. The decrease in adsorption capacity with increase in the adsorbent dose is mainly due to the increase of unsaturation of adsorption sites through the adsorption reaction. Another reason may be due to the particle interactions, such as aggregation, resulting from high sorbent concentration. Such aggregation would lead to decrease in total active surface area of the sorbent.

3.4 Effect of contact time on Cd(II) ion adsorption

Equilibrium time is one of the important parameters for an economical wastewater treatment system [21]. The experimental results relating to the effect of contact time on removal of Cd(II) are shown in Fig. 5. It can be clear from the ûgure that the removal of metal ions increased with increase in agitation time and attained maximum at 280min Cd(II) with removal of 76.56% onto the ACECM. The behaviour suggests that at the initial stage, sorption takes place rapidly on the external surface of the adsorbent.

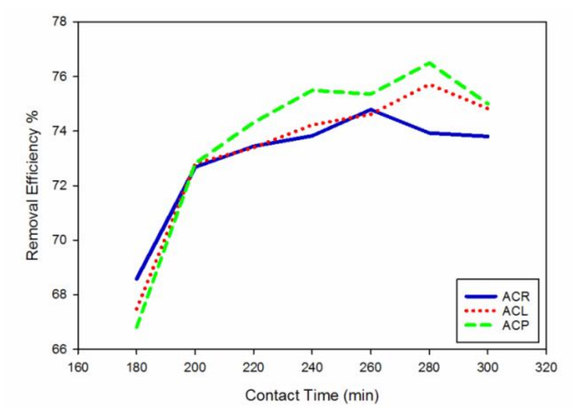

Fig.5: Effect of contact time on adsorption Cd (II) by ACECM

4. CONCLUSION

Activated carbon absorption process is also the best process of the removing the heavy metal from the wastewater. Bio-adsorbent are the most efficient cost effective and environment friendly because of not enough use of aquatic plant we can use to make the activated carbon which are giving the absorption result in this experiment we have ACECM like roots, petiole and leaf which are giving the best result for the absorption in all type of activated carbon the petiole gives the best result and then leaf. The results are for the absorption of Cd(II) ions is 76.56%.

REFERENCES

[1] W.W. Eckenfelder, "Industrial Water Pollution Control," 2th Ed., McGraw Hill, New York, 1989, pp. 104.

[2] J.W, Patterson Wastewater Treatment Technology, Ann Arbor, USA, 1977.

[3] M.L Barrow, and W.J. Weber, "Trace Elements in Sewage Sludge," J. Sci. Food Agric., 23, 1972, 93-110.

[4] M. Sitting, "Pollutant Removal Handbook," Noyes Data Corporation, New Jersey, 1973, pp. 69-72.

[5] P. J. Patterson, H.E. Allen, and J.J. Scala, "Carbonate precipitation for heavy metal pollutants," J. Water Pollut. Cont. Fed., 49, 1977, 2397-2410.

[6] G.McKay, "Use of adorbents for the removal of pollutants from wastewaters," CRS Press, Boca Raton, FL, 1995.

[7] K. Kadirvelu, C. Thamaraiselvi, and C. Nama-Sivaym, "Removal of heavy metals from industrial wastewaters by adsorption onto activated carbon prepared from an agricultural solid waste," Bioresource Tech., 76, 2001, 63-65.

[8] K.Kadirvelu, M. Palanival Alanival, R. Kalpana, and S. Ra-Jesvari, "Activated carbon from an agricultural by-product, for the treatment of dyeing industrial wastewater," Bioresource Tech., 74, 2000, 263-265.

[9] F.M. A.erro-Garcia, J. Ultrilla-Rivera, J. Rodri-Guez-Gordillo, and I. Bautista-Toledo, "Adsorption

of zinc, cadmium and copper on activated carbons obtained from agricultural by-products, Carbon, 26, 1988, 363-373.

[10] A.C. Lua, and J. Guo, "Activated carbon prepared from oil palm stone by one-step CO_2 activation for gaseous pollutant removal," Carbon, 38, 2000, 1089-1097.

[11] F.C. Wu, R. L. Tseng, and R.S. Juang, "Pore structure and absorption performance of the activated carbons prepared from plum kernels," J Hazard. Mater., B69, 1999, 287-302.

[12] K.A. Krishnan, T.S. Anirudhan, "Uptake of heavy metals in batch systems by sulûrized steam activated carbon prepared from sugarcane bagasse pith," Ind. Eng. Chem. Res. 41, 2002, 5085–5093.

[13] M. Ahmedna, W.E. Marshall, A.A. Husseiny, R.M. Rao, and I. Goktepe, "The use of nutshell carbons in drinking water ûlters for removal of trace metals," Water Res. 38, 2004, 1062–1068.

[14] A. Saeed, M. Iqbal, "Bioremoval of cadmium from aqueous solution by black gram husk (*Cicer arientinum*)," Water Res. 37, 2003, 3472–3480.

[15] J.C. Igwe, D.N. Ogunewe, A.A. Abia, "Competitive adsorption of Zn(II), Cd(II) and Pb(II) ions from aqueous and non-aqueous solution by maize cob and husk," Afr. J. Biotechnol. 4, 2005, 1113–1116.

[16] M. Kazemipour, M. Ansari, S. Tajrobehkar, M. Majdzadeh, and H.R. Kermani, "Removal of lead, cadmium, zinc, and copper from industrial wastewater by carbon developed from walnut, hazelnut, almond, pistachio shell, and apricot stone," J. Hazard. Mater. 150, 2008, 322–327.

[17] Z. Reddad, C. Gerente, Y. Andres, and P.L. Cloirec, "Adsorption of several metal ions onto a lowcost biosorbent: Kinetic and equilibrium studies," Environ. Sci. Tech., 36, 2002, 2067-2073.

[18] A. Zer, M.S. Tanyildizi, and F. Tmen, "Study of cadmium adsorption from aqueous solution on activated carbon from sugar beet pulp," Environ. Tech., 19, 1988, 1119-1125.

[19] D.Mohan, and K.P. Singh, "Single-and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse-an agricultural waste," Wat. Res. 36, 2002, 2304-2318.

[20] G. Cimino, A. Passerini, and G. Toscano, "Removal of Toxic Cations and Cr(VI) from Aqueous Solution by Hazelnut Shell," Wat. Res., 34, 2000, 2955-2962.

[21] K.Kadirvelu, and C. Namasivayam, "Activated carbon from coconut coir pith as metal adsorbent: adsorption of Cd(II) from aqueous solution," Adv. Environ. Res., 7, 2003, 471–478.

