e - ISSN – 2393-9672

European Journal of Environmental Ecology

Journal homepage: www.mcmed.us/journal/ejee

REMOVAL OF DIVALENT CADMIUM IONS FROM SYNTHETIC WASTEWATER USING BROWN MUSTARD (*BRASSICA JUNCEA*) LEAVES BIOMASS BY ADSORPTION PROCESS

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Article Info

Received 10/11/2017; Revised 30/11/2017
Accepted 11/12/2017

ABSTRACT

In this study, the adsorption behavior of brown mustard (*Brassica juncea*) leaves biomass, low-cost adsorbents, with respect to the removal of Cd (II) ions, has been studied in order to consider its application to the treatment of wastewater. The physicochemical properties of the brown mustard leaves biomass were predetermined. Batch adsorption experiments were conducted to study the effect of pH of the solution, adsorbent dose, contact time, initial metal ions concentration and temperature on adsorption of cd (II) ions from synthetic waste water. The results indicates that, the maximum removal of 98.8% of Cd (II) ions (C_o = 100 mg/L) was achieved at the optimum contact time of 150 min at the biomass dose rate of 3.0 g/100 mL. The effective removal of Cd (II) ions is observed at the pH of 5.5. The present finds suggest that, the selected brown mustard leaves biomass can be used to produce the best quality biocarbon for the removal of heavy metals from industrial wastewater.

Keywords: Brown mustard, biomass, cadmium, wastewater treatment.

INTRODUCTION

Industrial activities always discharge heavy metals to the aquatic environment which are considered to be highly toxic and may extremely damage natural aqueous environment [1, 2].

Among the heavy metals, cadmium is considered as one of the most toxic element. Cadmium pollution in environmental systems are due to several industrial sources such as electroplating, smelting, pigments, plastics, battery, mining and refining processes [3]. Due to its bioaccumulation property, cadmium is recognized as a human carcinogen [4]. Metal pollutants mainly affect the biological function of the organisms, reducing the self-purification capacity of water, interfering with the metabolic cycle and causing an increase in the concentration of metals in the food chain [5]. Ingestion in very small quantities can also cause health problems such as hypertension. The permissible USEPA limit of divalent cadmium ions in water is 5ppb.

Several conventional methods are widely utilized for the removal of these heavy metals from wastewater includes reduction, precipitation, ion-exchange, filtration, electrochemical treatment etc., [6]. Further, most of these methods are either costly or ineffective for metals removal particularly when metals are present at relatively low concentration in large volumes of wastewater [7, 8].

In comparison with the available techniques, adsorption process has been used as an efficient practical method with utilization of low-cost adsorbents, particularly agricultural based waste biomaterials [9]. Activated carbon is one of the most popular adsorbents for the removal of metal ions from aqueous solutions. Notwithstanding its widespread use in industries, activated carbon remains an expensive material. Hence, recent studies have focused on the search for new, inexpensive and efficient adsorbent materials.

A wide variety of materials such as water hyacinth plant [10], sugar beet pulp [11], dry cabbage leaves [12], *jatropha* seed husk [13], sugarcane bagasse [14], holly sawdust [15], rice straw [16], exhausted tea leaves [17], cow dung [18], cassava peel and rubber tree bark [19] and sorghum husk [20]. In this research, we studied the possibility of using the biomass of brown mustard leaves as adsorbent for removal of Cd (II) ions from the synthetic wastewater employed as a trial treatment system. The effects of pH, initial Cd (II) ions concentration, contact time and temperature on adsorption capacities were also evaluated.

MATERIALS AND METHODS

Preparation of biosorbent

A brown mustard (Brassica juncea) leaves biomass is used as sorbent in this study and was obtained from a local agricultural garden at Tamil Nadu, India. The plant leaves was collected and washed with deionized water for 30 minutes, shade dried, pulverized then stored in air-tight polythene containers for further use. The plant leaves and its biomass are shown in Figure 1(a) and (b).

Preparation of metal solution

Synthetic stock solution of Cd (II) (1000 mg/L) was prepared by dissolving separate 1.636 g of analytical grade $CdCl_2$ in 1000 mL of deionized water. All other concentrations of the metal ions were prepared by serial dilution of the stock solutions. The pH of the working solutions was adjusted using 0.1 N HCl and 0.1 N NaOH.

Batch Equilibrium adsorption Studies

Series of batch experiments were carried out in 250 mL iodine flasks according to the methods described in our earlier research work [21, 22] and to investigate how critical experimental parameters affect the adsorption process. The critical parameters investigated in this study include effects of pH, contact time, dosage, and initial metal ion concentrations. Solution temperature, volume of synthetic wastewater and rate of agitation were maintained constant throughout the study at 28 ± 2°C, 100 mL and 250 rpm for 150 min respectively.

The amount of metal ion adsorbed from synthetic wastewater and the percent removal of divalent cadmium ions was calculated by the following equations:

$$q_e = \left(\frac{C_o - C_e}{w} \right) \times V \quad (1)$$

$$\%\ \text{Removal} = \left(\frac{C_o - C_e}{C_o} \right) \times 100 \quad (2)$$

Where C_o and C_e are the initial and equilibrium concentrations of the adsorbate (mg/L), w is mass of biomass (g) and V is volume of the synthetic wastewater (mL) respectively.

RESULT AND DISCUSSION

Characterization of biomass

The important physico-chemical parameters such as moisture content (65.45%), loss of mass on ignition (94.50%), bulk density (0.85 g/mL), BET surface area (3.85 m^2/g) total organic content (82.65%), carbon (78.25%) and hydrogen contents (8.65%) are determined using many standard literatures found elsewhere [20, 23, 24].

Biosorption parameters

Effect of pH

The pH value is an important aspect for controlling the process of adsorption. It affects the surface charge of the adsorbents, the degree of ionization and the species of the adsorbate. The effect of pH on adsorption of divalent cadmium ions at the initial concentration (C_o = 100 mg/L) is shown in Figure 2. The maximum percentage removal of Cd (II) is 98.8 at the pH of 5.5. The principal driving force for metal ion adsorption is the electrostatic interaction, *i.e.* attraction between adsorbent and adsorbate [25]. The results indicate that, the ionic interaction with the adsorbent greater. Hence, the higher the adsorption of heavy metal was found.

Effect of amount of biomass

The effect of adsorbent dose on the percentage removal of Cd (II) metal ions from synthetic wastewater is shown in Figure 3. It is observed that as the weight of biomass increased from 0.5 to 4.0 g gradual increase in the percentage removal was obtained for metal ions. This is mainly due to an increase in the sorptive surface area and the availability of more active binding sites on the surface of the adsorbent with increase in adsorbent dose [26]. Further, increase in dose of adsorbent will not have any major changes.

Effect of contact time

The study on the effect of contact time is important parameters in any adsorption process, which establish the optimum equilibrium time for efficient removal of metal ion from aqueous solution. In the present investigation, the adsorption experiments were carried out with respect to contact time ranging from 30 to 210 min and the results are presented in Figure 4. The results indicated that metal adsorption increases steadily with increasing contact time. The percentage removal of Cd (II) from synthetic wastewater increases rapidly and reaches a value of 98.8% at 150 min. Further increase in contact time has a negligible effect on the percentage removal of Cd (II). The mechanism of solute transfer to the solid surface is primarily diffusion control process. Initially, the concentration gradient between the film and the solid surface is high and hence the transfer of solute onto the solid surface is faster [27].

Effect of initial metal ions concentration

The initial metal ions concentration is one of the most important aspects that determine the equilibrium concentration for the sorption process. The initial concentration of Cd (II) ions on the sorbent by varying the initial ions concentration as 25, 50, 75 and 100 mg/L for with respect to contact time for the removal of metal ions is shown in Figure.5. The percentage removal was increased with increase in Cd (II) concentration. The metal uptake mechanism is particularly dependent on the initial heavy metal concentration [28]. Further metal ions are adsorbed by specific active adsorption sites. This appears to be due to the increase in the number of ions competing for the available active sites on the surface [29].

Effect of temperature

The process of metal ions adsorption on the surface of an adsorbent has significantly influenced by system temperature. In the current research work, the role of temperature on the sorption process of Cd (II) ions was evaluated in the range of 30 to 80 ^{o}C and presented in the Figure 6. The increase in percentage of adsorption with rise in temperature may be due to the increase in the available thermal energy to certain extent only. It is observed that, from 30^{o}C to 60^{o}C, the Cd (II) ions removal is slowly increasing (98.8%) and then dropping. However, higher temperature induces higher mobility of the adsorbate causing desorption [30].

Comparatives studies on various adsorbents

The application of various low-cost adsorbents in the removal of selected heavy metals form industrial and or synthetic wastewater is illustrated the following Table 1. In the current research brown mustard leaves biomass is used for the removal of heavy metal ion Cd (II) ions from synthetic wastewater as model pollutants. It shows very good results in parallel with other adsorbents.

Table 1. Removal efficiency of some low-cost adsorbents.

S.No.	Metal	Adsorbents	Maximum Removal (%)	Reference
1	Cd	Sodic Bentonite	97.62	[5]
2	Cd	Tridax procumbens (Asteraceae)	98.00	[21]
3	Cd	African palm fruits	99.23	[31]
4	Cd	Moringa stenopetala	82.70	[32]
5	Cd	Wheat straw *(Triticum aestivum)*	90.18	[33]
6	Cd	Brown mustard leaves biomass	98.80	Present Study

Fig 1. (a). Brown mustard (*Brassica juncea*) plant

Fig 1. (b). Green leaves biomass

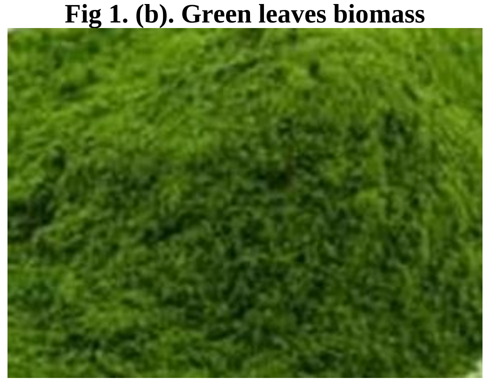


Fig. 2. Effect of pH on the removal of Cd (II) ions.

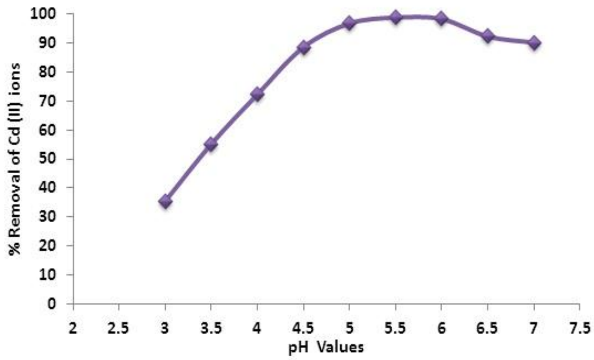


Fig 3. Effect of amount of biomass on the removal of Cd (II) ions.

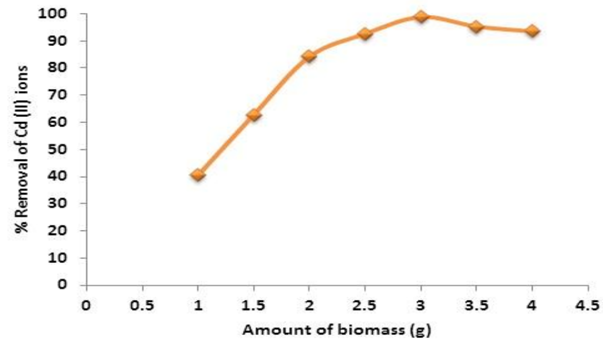


Fig. 4. Effect of contact time on the removal of Cd (II) ions.

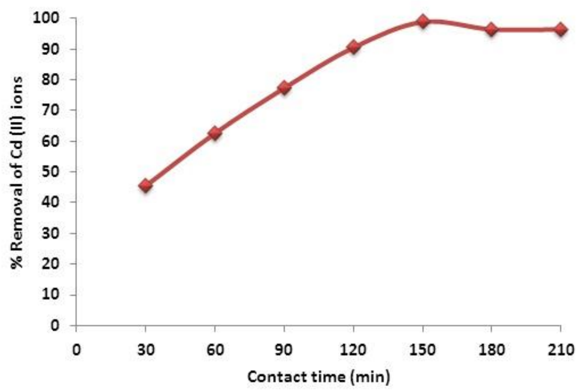


Fig. 5. Effect of initial concentrations on the removal of Cd (II) ions.

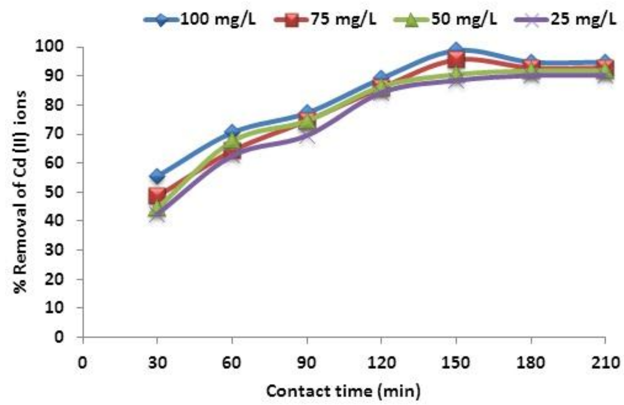
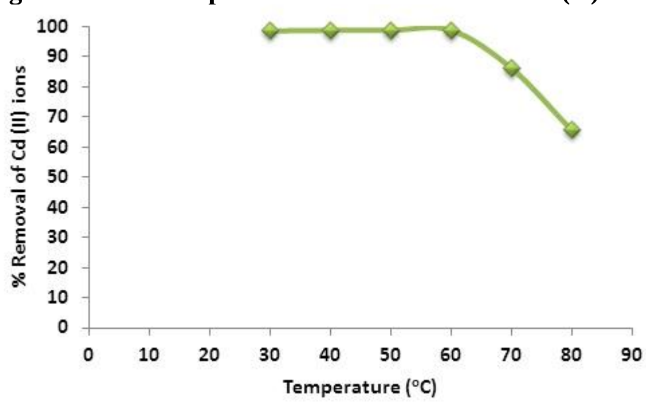


Fig. 6. Effect of temperature on the removal of Cd (II) ions.



CONCLUSION

It is mainly understood that, the established experimental conditions plays an important role on the adsorption process of heavy metals ions removal as well as on the adsorption capacity. The results indicated that, the Cd (II) ions removal process is mainly depends on the pH and contact time. The maximum removal of 98.8% of Cd (II) ions (C_o = 100 mg/L) was achieved at the optimum contact time of 150 min at the biomass dose rate of 3.0 g/100 mL. The effective removal of Cd (II) ions is observed at the pH of 5.5. It is shown that brown mustard leaves biomass has a relatively high adsorption capacity for the selected heavy metal. The present finds suggest that, the selected brown mustard leaves biomass can be used to produce the best quality biocarbon for the removal of heavy metals from industrial wastewater.

REFERENCES

1. Feng N, Guo X and Liang S. (2009). Adsorption study of copper (II) by chemically modified orange peel. *Journal of Hazardous Materials,* 164: 1286 – 1292.
2. O'Connell DW, Birkinshaw C and O'Dwyer TF. (2008). Heavy metal adsorbents prepared from the modification of cellulose: A review. *Bioresource Technology,* 99: 6709 – 6724.
3. Tsezos M. (2001). Bioadsorption of metals. The experience accumulated and the outlook for technology development. *Hydrometallurgy,* 59: 241 – 243.
4. Taqvi SIH, Hasany SM and Bhangar MI. (2007). Sorption profile of Cd (II) ions on to the beach sand from aqueous solutions. *Journal of Hazardous Materials,* 141: 37 – 44.
5. Galindo LSG, de Almeida Neto AF, da Silva MGC and Adeodato Vieira MG. (2013). Removal of cadmium (II) and lead (II) ions from aqueous phase on Sodic bentonite. *Materials Research*, 16(2): 515 – 527.
6. Mousavi H, Hosseynifar A, Jahed V and Dehghani SAM. (2010). Removal of lead from aqueous solution using waste tire rubber ash as an adsorbent. *Brazilian Journal of Chemical Engineering,* 27 (1): 79 – 87.
7. Rangel VMM, Martínez RC, Villanueva RA, Garnica Romo MG and Flores HEM. (2012) As (V) biosorption in an aqueous solution using chemically treated lemon (*Citrus aurantifolia swingle*) residues. *Journal of Food Sciences*, 77(1): T10 – T14.
8. Mishra V, Balomajumder C and Agarwal VK. (2012) Kinetics, mechanistic and thermodynamics of Zn (II) ion sorption: a modelling approach. *Clean Soil Air Water,* 40(7): 718 – 727.
9. Sreejalekshmi KG, Krishnan KA and Anirudhan TS. (2009) Adsorption of Pb (II) and Pb (II) citric acid on sawdust activated carbon: Kinetic and equilibrium isotherm studies. *Journal of Hazardous Materials,* 161: 1506 – 1513.
10. El-Wakil AM, Abou El-Maaty WM and Awad FS. (2014). Removal of lead from aqueous solution on activated carbon and modified activated carbon prepared from dried water hyacinth plant. *Journal of Analytical and Bioanalytical Techniques*, 5: 187 DOI:10.4172/2155-9872.1000187.
11. Pehlivan E, Yanık BH, Ahmetli G and Pehlivan M. (2008). Equilibrium isotherm studies for the uptake of cadmium and lead ions onto sugar beet pulp. *Bioresource Technology,* 99: 9, 3520.
12. Kamar FH, Nechifor AC, Mohammed Ridha MJ, Mohammed Altaieemi MB and Nechifor G. (2015). Study on adsorption of lead ions from industrial wastewater by dry cabbage leaves. *Revista de Chimie (Bucharest),* 66 (7): 921 – 925.
13. Shi B, Zuo W, Zhang J, Tong H and Zhao J. (2016). Removal of lead (II) ions from aqueous solution using *Jatropha Curcas* L. seed husk ash as a biosorbent. *Journal of Environmental Quality*, 45:984 – 992.
14. Salihi IU, Kutty SRM and Isa MH. (2017). Adsorption of lead ions onto activated carbon derived from sugarcane bagasse. *Materials Science and Engineering,* 201: 012034, DOI:10.1088/1757-899X/201/1/012034.
15. Samarghandi MR, Azizian S, Shirzad Siboni M, Jafari S.J and Rahimi S. (2011). Removal of divalent nickel from aqueous solutions by adsorption onto modified holly sawdust: Equilibrium and kinetics. *Iranian Journal* of *Environmental Health Science* & *Engineering,* 8(20: 181 – 188.
16. Mousa WM, Soliman SI, El-Bialy AB and Hanaa A. Shier. (2013). Removal of some heavy metals from aqueous solution using rice straw. *Journal of Applied Sciences Research,* 9(3): 1696 – 1701.
17. Shrestha B, Kour J and Ghimire KN. (2016). Adsorptive Removal of heavy metals from aqueous solution with environmental friendly material – Exhausted tea leaves. *Advances in Chemical Engineering and Science,* 6: 525 – 540.
18. Ojedokun AT and Bello OS. (2016). Sequestering heavy metals from wastewater using cow dung. *Water Resources and Industry,* 13: 7–13. doi.org/10.1016/j.wri.2016.02.002.
19. Vasudevan M, Ajithkumar PS, Singh RP and Natarajan N. (2016). Mass transfer kinetics using two-site interface model for removal of Cr (VI) from aqueous solution with cassava peel and rubber tree bark as adsorbents. *Environmental Engineering Research*, 21(2): 152 – 163.
20. Tatah VS, Otitoju O, Ezeonu CS, Onwurah INE and Ibrahim KLC. (2017). Characterization and Adsorption Isotherm Studies of Cd (II) And Pb (II) Ions Bioremediation from aqueous solution using unmodified sorghum husk. *Journal of Applied Biotechnology & Bioengineering*, 2(3): 00034. DOI: 10.15406/jabb.2017.02.00034.
21. Singanan M. (2011). Removal of lead (II) and cadmium (II) ions from wastewater using activated biocarbon. *ScienceAsia,* 37: 115 – 119.
22. Singanan M and Peters E. (2013). Removal of toxic heavy metals from synthetic wastewater using a novel biocarbon technology. *Journal of Environmental Chemical Engineering,* 1: 884 – 890.
23. Silgado KJ, Marrugo GD and Puello J. (2014). Adsorption of chromium (VI) by activated carbon produced from oil palm endocarp. *Chemical Engineering Transactions,* 37:721 – 726.
24. Krista S. Walton, Randall Q. Snurr (2007). Applicability of the BET method for determining surface areas of microporous metal − organic frameworks. *Journal of the American Chemical Society,* 129 (27): 8552 – 8556.

25. Krishna D and Padma Sree R. (2013). Removal of chromium from aqueous solution by Custard apple (Annona Squamosa) peel powder as adsorbent. *International Journal of Applied Science and Engineering,* 11(2): 171 – 194.
26. Barka N, Qourzal S, Assabbane A, Nounah A and Ait-Ichou Y. (2011). Removal of reactive yellow 84 from aqueous solutions by adsorption onto hydroxyapatite. *Journal of Saudi Chemical Society,* 15: 263 – 267.
27. Mulani K, Daniels S, Rajdeo K, Tambe S and Chavan N. (2013). Adsorption of chromium (VI) from aqueous solutions by coffee polyphenol – formaldehyde / acetaldehyde resins. *Journal of Polymers,* http://dx.doi.org/10.1155/2013/798368.
28. Amiri MJ, Fadaei E, Baghvand A and Ezadkhasty Z. (2014). Removal of heavy metals Cr (VI), Cd (II) and Ni (II) from aqueous solution by bioabsorption of *Elaeagnus Angustifolia*. *International Journal of Environmental Research*, 8(2):411 – 420.
29. Sayed G, Dessouki HA and Ibrahim SS. (2010). Biosorption of Ni (II) and Cd (II) ions from aqueous solutions on to rice straw. *Journal* of *Chemical* Sciences, 2**:** 1 – 11.
30. Rane NM, Sapkal RS, Sapkal VS, Patil MB and Shewale SP. (2010). Use of naturally available low cost adsorbents for removal of Cr (VI) from waste water. *International Journal of Chemical Sciences and Applications,* 1(2): 65 – 69.
31. Abdulrazak S, Hussaini K and Sani HM. (2016). Evaluation of removal efficiency of heavy metals by low-cost activated carbon prepared from African palm fruit. *Applied Water Science,* 7 (6): 3151–3155. https://doi.org/10.1007/s1320.
32. Mataka LM, Sajidu SMI, Masamba WRL and Mwatseteza JF. (2010). Cadmium sorption by *Moringa stenopetala* and *Moringa oleifera* seed powders: Batch, time, temperature, pH and adsorption isotherm studies. *International Journal of Water Resources and Environmental Engineering,* 2(3): 50 – 59.
33. Ali SZ, Athar M, Salman M Din MI. (2011). Simultaneous removal of Pb (II), Cd (II) and Cu (II) from aqueous solutions by adsorption on *Triticum aestivum* – A green approach. *Hydrology*: *Current Research,* 2:118. DOI:10.4172/2157-7587.1000118.