https://africanjournalofbiomedicalresearch.com/index.php/AJBR
Afr. J. Biomed. Res. Vol. 27 (October 2024); 1043-1051

Research Article

Adsorptive Study of Cadmium Removal from Synthetic Solution Using Newly Developed Activated Carbon from Bark of *Butea monosperma*

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Abstract
Due of the rapid growth of the social economy and increase in the population, human beings continue to undertake processing and commercial manufacturing activities of heavy metals which has caused serious damage to the environment and human health. One of the most toxic heavy metal ion that are non biodegradable is Cadmium. Cadmium is agglomerate in blood causes verisimilitude of symptoms such as high blood pressure, kidney damage and destruction of red blood cell. There are several technology like filtration,ion exchange, reverse osmosis, solvent extraction and adsorption are available for removal of cadmium. Among all adsorption is best promission low cost method. In the current investigation, the adsorption potentiality of activated carbon developed from *Butea monosperma* bark for evacuation of cadmium from waste water has been studied regarding to different parameters like the pH effect, adsorbent dose, contact time and initial metal ion concentration. The maximum cadmium removal of 93.50% is obtained under optimal operating conditions at pH 6.0. Cadmium removal from synthetic solution increases with an increase in contact time and equilibrium was obtained at 120 minute. The higest adsorption of cadmium was observed at 6.0 g/L of dose of adsorbent. This study established evidence that the newly developed activated carbon from *Butea monosperma* bark could be utilized as a economical and more energy efficient adsorbent to replace cadmium from aqueous solution and can be successfully used for wastewater treatment.

Keywords: Activated Carbon, Adsorption, Bark of *Butea monosperma*, Cadmium.

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Received 20/10/2024, Acceptance 26/10/2024

DOI: https://doi.org/10.53555/AJBR.v27i3.3129

Introduction

Water is the most significant resource for all living things throughout the world [1-4]. However, water pollution is considered the greatest stimulating issue all over the world, especially in developing countries like India [4-6]. The main cause of water pollution is urbanization, industrialization and population growth in the past one and half-century. Among these, various industries dischage various toxic heavy metals, organic dyes, pharmaceuticals waste, petroleum products into water [7-9,71]. Owing to their noxiousness and bioaccumulation, they supply enormous hazards to living things [10-12]. Some metal ions can have toxic effects on many human lives and the environment[13-15,71]. Metals that are toxic to humans and the ecological environment include copper, chromium, lead, mercury, cadmium, nickel, iron, and cobalt [16-18]**.** Although these heavy metals are found in low amounts in environment , they can cause serious problems for enrionment and health [19-20]. Cadmium is one of the most toxic heavy metals found in the environment. Cadmium has many applications in various industrial sectors such as plastics, alloys, anti corriosn coating, pigments, stabilizers in rechargeable batteries, and solar energy capture devices. However, theseuses lead to serious consequences of cadmium toxicity in wastewater [21]. Cadmium is classified as a e human carcinogen by the United States Environmental Protection Agency (US EPA).The US EPA sets the maxium cadmium level in drinking water as 0.005 mg/L, while the World Health Organization (WHO) limits this value to 0.003 mg/L [22] . Levels above this limit can cause in skin, kidney, lung, bladder and liver cancer as well as heart disesase and stroke, tissue damage and anemia [23,24].

Various technologies such as precipitation [25,26], ion exchange [27,28], adsorption [29,30], membrane filtration [31-32], reverse osmosis [33-34], solvent extraction [35], electro dialysis and electrochemical treatment [36,37], photocatalysis [38,39] are used to remove heavy metals from contaminated water. Most of these technologies cannot be eliminated effectively and have disadvantages such as labor intensive,high energy consumption, high cost,high drug use,, biological and destructive drug production and environmental protection [40,41,42]. Amongst these, adsorption technology attracts attention in the removal of metals from wastewater due to its advantages such as cost effectiveness, high efficiency, harmlessness and easy purification[43]. Many studies have been focused on preaparation of activated carbons from cheaper and more readily available materials such as various biomass, agricultural products, clay, corn cob and fly ash [44-46], green coconut shell[47], sugarcane bagasse[48,49], coffee husk[50], rice husk[51], mango kernel[52], maize cob[53], sawdust[54], hazelnut shell [55], groundnut hull [56], pea pod peel [57], avocado seed kernel [58], tea waste [59] and olive bagasse[60], coir pith [61], coco-nut tree saw dust [62], almond shells, olive and peach stones [63], oil palm stones [64] and plum kernels [65]. Other agricultural wastes such as nut shells [66], black gram husk [67], almond, pistachio shell and apricot stone[68] 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.

In the recent study, Butea Monosperma bark were used because they are the locally available material for the preparation of Activated carbon material. The activated carbon from Bark of Butea Monosperma which is characterized by large surface area, high micropore volume and higly adsorption efficiency,potentially can be used to prepared adsorbent for elimination fo water pollutants. Therfore newly prepared BMAC are considered excellent adsorbent becuses of their low cost and highly effective adsorbent. The main goal was to investigate the possibility of application of BBMAC as a adsorbent to eliminate Cd(II) from aqueous solution. Ther are few factor that effect the adsorption process such as pH of solution, adsorbent dose, contact time and initial metal concentration were studied.

Materials and Method

Chemicals and Reagents :

In this study Cadmium nitrate, sodium hydroxide, and hydrochloric acid are used of analytical grade and purchased from Global Marketing,Nagpur (India). The stock solution of 1000 mg/L Cd(II) were prepared by dissolving appropriate quantity of $Cd(NO_3)_2$ in deionized water. For required concentration, serial dilutions were prepared using deionized water. The pH of the test solutions was adjusted using AR Grade 0.1N HCl or 0.1N NaOH.

Preapartion of Activated Carbon from *Butea Monosperma* Bark (BBMAC):

The bark of Butea monosperma tree is collected in a native forest (Fig A). The bark were cut into small pieces and washed throughly with water to remove sand. The cleaned material is then placed in formaldehyde to prevent colour the formation in the aqueous solution. Formaldehyde treated material were washed several time with distilled water. After drying, the small pieces of bark is pyrolyzed and carbonized at 750^0C for 5 to 6 hr. In this way, non volatile substance are removed and converted into charcoal. The charcoal were placed in a microwave oven and run the microoven for 30 minuter for activation process. Activated carbon particles were grounded and sieved in 120-200 mm size. The newly produced activated carbon (Fig. B) is then washed with double distilled water and dried at 105ºC for 4 to 5 hr. in oven and store in desicator (71)

Characterization of BBMAC:

The surface area of the preapared BBMAC was estimated by using Brunauer-Emmett- Teller method using Coulter SA3100 instrument, A scanning electron microscope (model JEOL 6390LV) was used for Scannning electron microscopy (SEM); Fourier Transform infrared spectrometer (FTIR)(model : Thermo Nicolet Avatar 370) analysis was perform to identity the different functional group associated with the material and X-ray Diffractometer (model: Bruker AXS D8 advance) was used for X-ray powder diffractograms. (FTIR) analysis was performed to identify the different principal functional groups using a spectrometer (6700 FTIR; Nicolet, America)

Adsorption Studies:

Standard solutions were prepared from stock solution of Cd(II) stock. The batch equilibrium method is performed for removal of Cd(II) using BBMAC. Batch experiments were carried out at room temperature (29^0C) to study the effect of pH, contact time, mass of adsorbent and initial cadmium ion concentration. Adsorption experiment were carried out at different variables to study the best removal condition. Affecting varibales of adsorption were mention in table 1. A 100 ml solution of the metal ions was used for each experiment under set condition. All experiments were performed at room temperature and a fixed shaking speed of 250 rpm. The filtrate was analysed by Atomic Absorption Spectrophotometer with wavelength of 228 nm for Cd(II) to determine the final concentration of Cd(II) ion. The adsorption capacity q_t (mg/g) was calculated using equation (1) and the percent removal was calculated using euquation (2) equation:

$$q_t = \frac{(C_0 - C_e)\,V}{W} \quad \text{-----------------------------------}1$$

$$R_e = \left(\frac{C_0 - C_e}{C_0}\right) X\ 100 \quad \text{------------------------------}2$$

where q_t (mg/g) is the adsorption capacity of adsorbent for Cd(II) at time t (min) and C_0 and C_e (mg/L) are the initial and equilibrium metal ion concentration in solution respectively. V (L) and W (g) are the volume of the adsorption solution and the weight of the dry adsorbent used, respectively.

Table No. 1 Different Varibles affecting adsorption of BBMAC

Parameters	Variables	Costants
Contact Time (10 to 150 min)	Contact Time	Agitation speed, Temperature, pH, adsorbent dose, initial concentration
Dose Range (1 to 10 gm/L)	Adsorbent Dose	Shaking speed, Temperature, pH, Contact time, initial concentration
pH Range (1 to10)	pH	Shaking speed, Temperature, Contact Time, Dose of adsorbent, initial concentration
Effect of initial ion concentration (10 to 100 mg/L)	Concentration	Temperature, Shaking speed, Contact Time , Dose of adsorbent, pH

Fig A : Bark of *Butea Monosperma*

Fig. B: Activated Carbon prepared from Bark of BM

Result and Discussion

Characterization of BBMAC

FTIR Analysis: FTIR spectoscopy is useful for indentifying and characterizing different function groups associated with adsorbent surface. The BBMAC spectrum show in Fig.1 and shows different absorption peaks indicating the complexity of BBMAC. The band at 3420 cm^{-1} represents –OH and –NH group stretching. It can be proven that the absoption peak at 2960 cm^{-1} is in the aliphatic C-H group. The peak at 1740cm^{-1} appears in the -C=O group, similar to the carboxylic or ester group. The band near to 1620 cm^{-1} indicating the –C=O group (amide band is mostly a stretch bands). The peak at 1520 cm^{-1} indicates that –C=O group corresponds to the carbonyl stretching band.(71)

SEM Analysis: SEM image is very useful for describing the porous heterogeneity and surface morphological structure of the material. Fig. 2 shows SEM image of BBMAC. SEM micrograph shows that BBMAC surface has a clean porous structure. It was observed that there were very small and large holes on the surface of the BBMAC. Due to the presence of the hollow holes similar to the adsorbent material, BBMAC has a large surface area and high adsorption efficiency. All the heavy metal ions adsorption methods depends on the size of the void on the surface of activated carbon.(71)

XRD Analysis: The XRD is useful to analyze physical properties such as phase composition, crystal structure and orientation of powder, solid and liquid material.The X-ray diffraction pattern of BBMAC is shown in Figure 3. The material is an amorphous characteristic in the comprehensive X-ray diffraction pattern structure, indicating an extremely disordered structure. The elevation is found around to 2θ value of around 22° and small peaks near 16° and 35° associated with crystalline cellulose [69].

Determining the specific area is most important properties of adsorbent material as it indicates the necessary active site for adsorption. The calculated values of S_{BET} for BBMAC was found to be 287.20 m^2/g

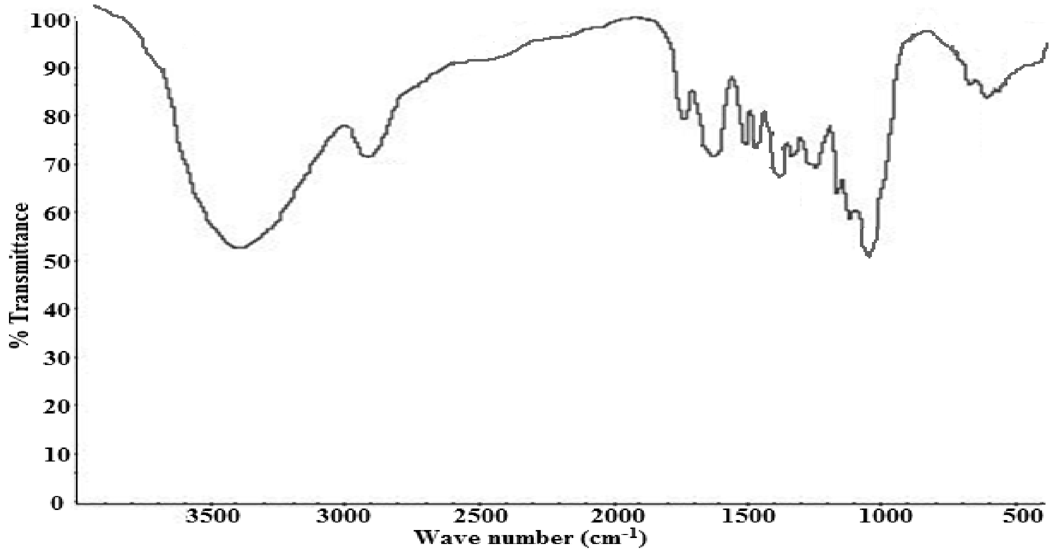

Fig. 1: FTIR of activated carbon of Bark of *Butea Monosperma*(BBMAC)

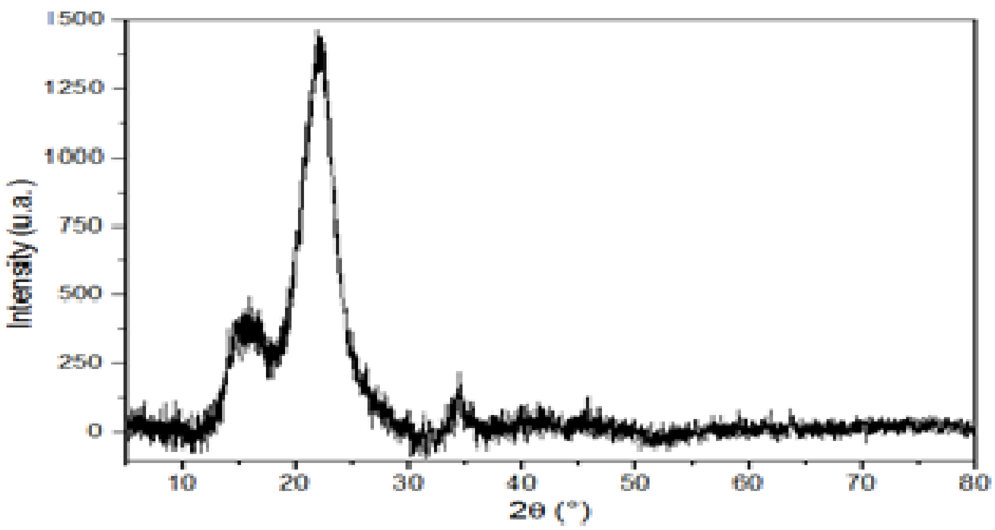

Fig. 3. X-ray diffractogram of BBMAC

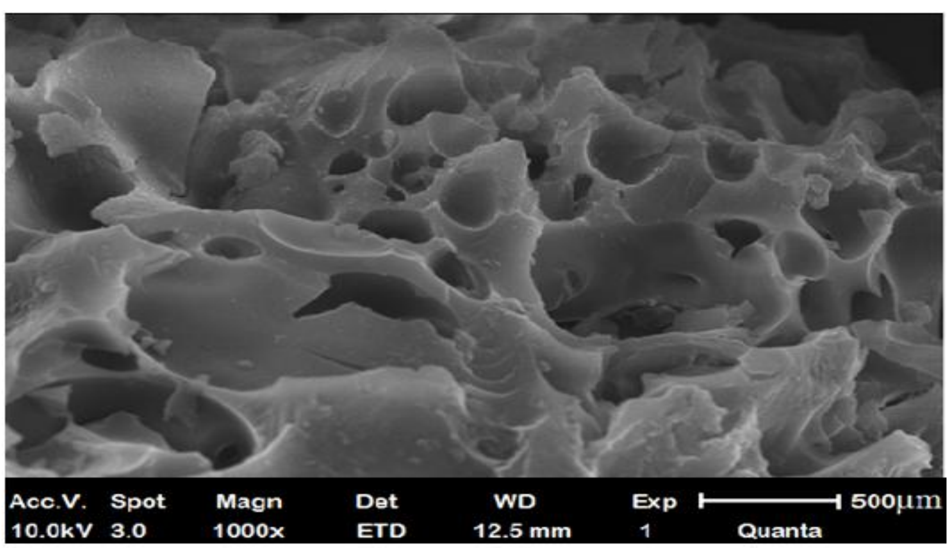

Fig. 2 : Scanning electron micrographs (SEM) of BBMAC

Effect of pH : The pH of the solution affects the surface charge of adsorbent, the degree of dissociation and the speciation of the surface function group [70]. The effect of pH on the adsorption of Cd(II) ion was studied by varied pH from 1 to 10 at 100mg/L metal concentration for 90 min. and 5 g/L BBMAC adsorbent dose (shown in Fig.4.) .The Cd(II) adsorption on the prepared BBMAC increases with the increase in pH of solution. We observed that the removal of Cd(II) is found to increase as the pH increases beyond 3 and at above the pH 6, uptake is 90%. The removal percentage of Cd(II) increases from 80% to 92% at pH 4 to 6 and is appreciably best at 6.0 pH. Removal percentage of Cd (II) nearly constant after the pH 8. Thus it may be concluded that at lower pH ion exchange reaction involving metals are in competition with the higher concentration of H^+in the solution whereas at higher pH value, metal removal is increasesed due to formation of metal oxide precipitation.

Effect of Contact Time : Equilibrium time is an important factor in wastewater treatment.The effect of contact time on the adsorption of Cd(II) onto the adsorbent BBMAC was studied in the range of 10-150 min with the pH was adjusted 6.0 in the solution with initial concentration 100 mg/L with 5 gm of adsorbent shown in Fig.5. We observed that initially the percentage removal of cadmium is very fast during the intial period of contact time and it is maximum i.e. 93.50% removal is at 120 min. Thus equilibrium time for maximum removal of Cadmium was attaine at 120 min. In the beginning, rapid removal of Cd(II) is due the high availability of active sites on the adsorbent surface. The speed of removal of Cd(II) is slow down nearly to equilibrium position because of acuumulation of metallic element molecules on the surface of the adsorbents hinders diffusion of the molecules into the pores .

Effect of Adsorbent Dose : The dose of adsorbent used to determine both the effective adsorption and the amount to be used economically too.To determine the highest amount of adsorbent required for maximum removal of Cd(II), the adsorbent dose was found out by changing the quantity of BBMAC from 1 to 10 g/L at pH 6, initial metal ion concentration of 100mg/L, and 120 min contact time which shown in Fig.6. It can be seen from Figure 6 shows that the Cd(II) removal rate increases as BBMAC dose increases. The maximum removal of Cd(II) was found at 93.5% of 6 g of adsorbed adsorbent. The main reason for this is easy access to the void and the availability of surfacearea for the adsorbent. When the concentration of the adsorbent is reached, the removal efficiency remains unchanged due to the maximum adsorption setting.

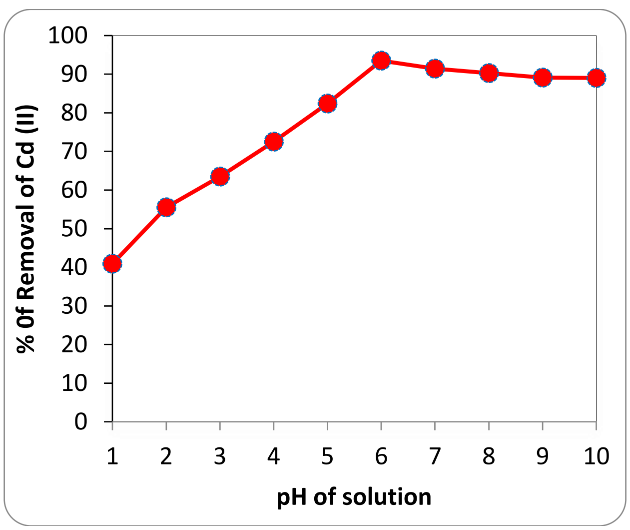

Fig.4. pH effect on Cd(II) adsorption

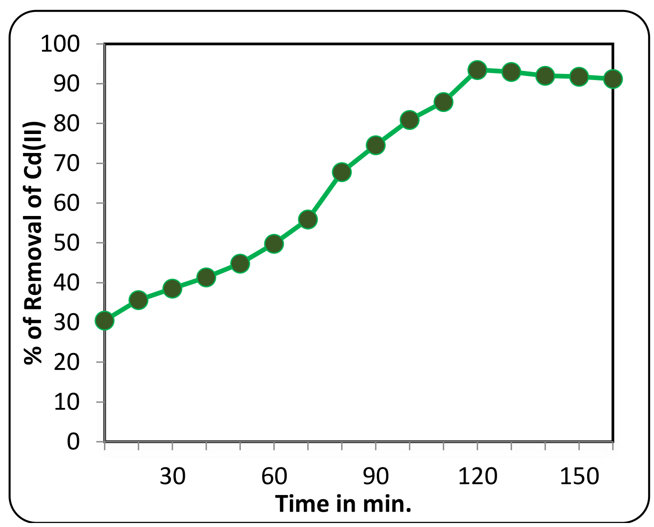

Fig.5.Effect of Contact time

Impact of initial metal concentration: The effect of initial Cd(II) concentrations on the efficiency of adsorption was investigated over the concentration range from 10 to 100 mg/L with mass of adsorbent (4 g/L), contact time (120 min) and pH of the solution (7) retain constant as shown in fig.7. The result shows a decrease in Cd(II) removal from 94% to 35% when the adsorbate concentration changed from 10 to 100 mg/L At lower concentration of adsorbate the ratio of surface-active sites to the total metal ions in the solution is high and hence all metal ions interact with the adsorbent and are removed quickly from the solution. However, the amount of metal ions adsorbed per unit weight of adsorbent, q, is higher at high concentration. According to these results, the initial Cd^{+2} ions concentration plays an important role in the adsorption capacities

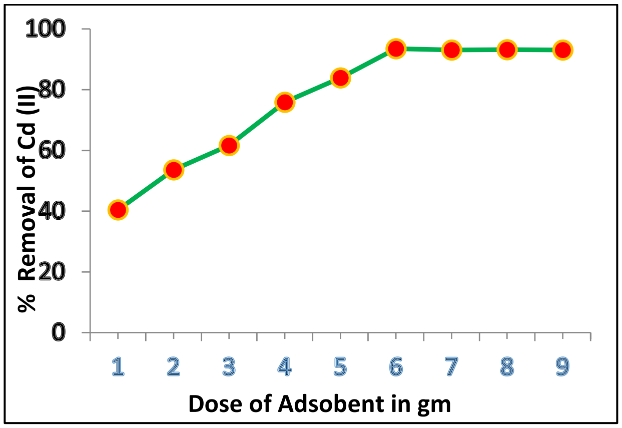

Fig.6. Effect of Adsorbent dose

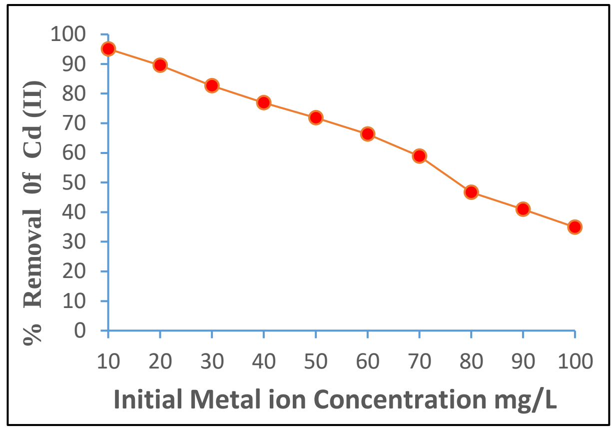

Fig.7. Effect of concentration on Cd(II) adsorption

Conclusion:

The removal of toxic heavy metals as well as organic pollutants by the adsorption process onto surface of activated carbon synthesized from waste material has the advantages like low cost, high efficiency, environmental friendly and minimum level of toxicity. Bark of *Butea monosperma* were used for preparation of activated carbon as a adsorbent to remove Cd(II) from the wastewater. Adsorbent was successfully prepared and confirmed by characterization studied such as XRD, SEM and FTIR. The maximum removal percentage of Cd(II) ion using BBMAC were achieved at 120 min. The percentage removal of Cd(II) ions increased by increasing the adsorbent dose. As initial concentration of metal ions increasesd, the percentage of removal of metal ion using BBMAC decreased. The maximum removal of Cd(II) ion by BBMAC were carried out at acidic pH 6. Therfore we proved that the newly preapred BBMAC material has the potential to be used as a catalyst for cost effective and easy remval of Cd(II) ions from wastewater.

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