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Effect Bed Height on Adsorption of Cu(II) by Using Corncob Based Activated Carbon

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ABSTRACT
A variety of toxic and harmful matters contribute to the severe impacts of water sources. Toxic pollutant such as heavy metals tend to deteriorate the environment vigorously due to its mobility. In this study, corncob based activated carbon (CCAC) was prepared for Cu (II) adsorption from aqueous solution. By using 4 cm and 8 cm of bed height in the column test, the time taken to reach the saturation level were 900 and 1150 minutes, respectively. The exhaustion period for Cu (II) for bed height 4 cm and 8 cm were 800 and 1105 minutes, respectively. For 50% breakthrough, the period of 350 min and 600 min for 4 cm and 8 cm bed height, respectively were obtained. The removal efficiency for both bed heights showed more than 95% (100mg/L) which indicate the feasibility of CCAC as an adsorbent for Cu (II) removal.

Keywords: *Activated carbon, adsorption, column study, bed height, Cu(II), corncob*

1. INTRODUCTION

Water is the most precious substance for living things on earth. Human started their civilization besides the rivers because of the source of water. Industrialization, however, has had significant implications for the source of life; water [1]. Industrial activities discharge a variety of toxic and harmful matters which bring severe impacts to the water environment. Major industries like mining, electroplating, battery manufacturing, metal smelting, spinning, glass and ceramics producing are contributing to the release of heavy metals such as copper, zinc and chromium to the environment [2]. Besides being known as a toxic substance, most metals that enter water bodies are at a high concentration which could severely affect human health and the environment [3-5].

Researchers all around the world have been succeeded in developing many technologies to remove heavy metals from wastewaters namely membrane filtration, ion exchange, chemical precipitation, electrocoagulation, and so on [6]. Lately, emphasis on the adsorbent with low-cost precursors particularly from agro wastes for the heavy metals removal attracted more attention. These biomaterials signify a fascinating and attractive alternative as adsorbents due to their high surface area and low-cost. Furthermore, agro wastes are plentiful, renewable, and biodegradable resources that can adsorb heavy metals from wastewater [4]. Certain agro wastes such as apricot stone [7], black sapote seeds [8], honeydew [9], corn straw [10], long-root *Eichhornia crassipes* [11], peanut shell [12], corn cob, wheat bran, rice husk and soybean shell [13] have been converted into adsorbents for the removal of heavy metals in wastewaters.

High consumption of water by industries like metal finishing, tanneries, electronics, petrochemical, electroplating, and the textile mill is one of the reasons why heavy metals contamination problem is getting worse every day. Therefore, a smart yet simple solution is required. As compared to other methods, the adsorption process via activated carbon (AC) is well recognized to be a more superior method due to several advantages that it poses such as ease of design, simple operation, and high efficiency. Though, the production expenses of commercial coal-based AC are high enough. Thus, to overcome the problem, producing AC with high adsorption performance from an alternative material that is low-cost and readily available is a need.

The corn industry only uses the edible part of corn whereas the corncob is dumped as waste or used for feedlot materials. The conversion of corncob into AC to treat wastewater is beneficial to the community and added more value to the corn commodity. It also offers a cheap alternative to AC's precursor.

2. EXPERIMENTAL

Corncob as precursor was obtained from Bukit Mertajam, Penang, Malaysia. Copper sulfate was supplied by Sigma-Aldrich (M) Sdn. Bhd, Malaysia. Nitrogen and carbon dioxide were used for the carbonization and activation processes, respectively.
The setup consists of a stainless steel vertical tubular reactor equipped with programmable temperature controller and gas system where the gas flow rate was adjusted to the needed level N_2 and CO_2 gases flow rates were determined by the gas flow meters (Model Dwyer, US). Carbonization (temperature 500ºC, 30 min, N_2 flowrate 150 mL/min) of the corncob followed by activation step (temperature 700ºC, 1 hr, CO_2 flow rate 150 mL/min) were done inside a vertical stainless steel reactor. The reactor was positioned within a vertical tubular furnace with a programmable controller (Model Carbolite, USA).
Fixed bed study was carried out for determining the performance of corncob to remove Cu (II) from aqueous solution. The column is made from Perspex with an inner diameter of 25 mm was used as shown in Figure 1. The particle size of 2.0-4.75 mm was used with porosity corncob was 0.68. Glass wool and wire mesh were used to prevent the loss of CCAC particles. The synthetic wastewater was pumped by using the Master-flex peristaltic pump into the column. The peristaltic pump was adjusted with various up-flow rate to prevent channeling. The effect of bed height on fixed bed column system was investigated by changing the bed heights from 4 cm to 8 cm. The solution flow rate and inlet Cu(II) concentration were fixed at 25 mL/min and 100 mg/L, respectively.

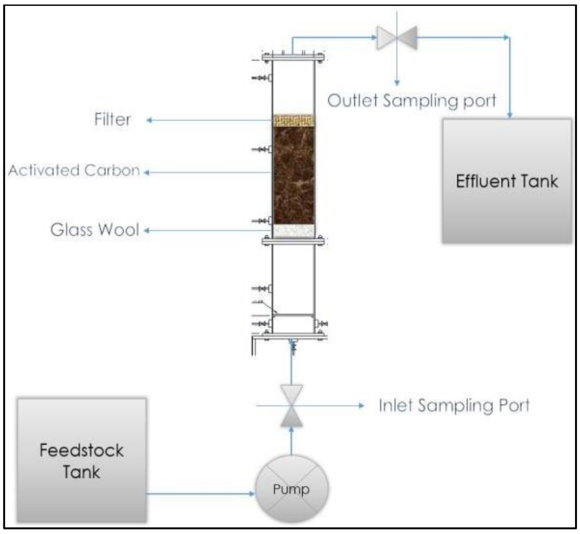


Figure 1 Schematic diagram of fixed bed study

3. RESULTS AND DISCUSSION

3.1 Characterization of samples

3.1.1 Surface area and pore characteristics

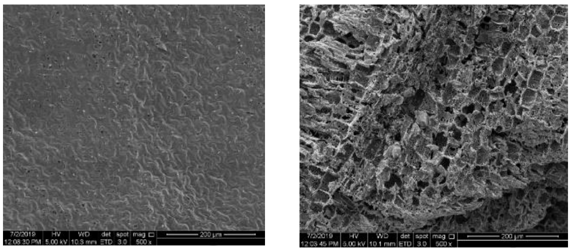
The surface area and pore characteristics of the sample are shown in Table 1. The CCAC sample given a relatively high BET surface area, which was 458.30 m^2/g with a total pore volume of 0.2248 cm^3/g and an average pore diameter of 3.42 nm. The high surface area and pore volume were contributed by the activation process in the microwave using CO_2 as the activating agent. The diffusion of CO_2 molecules into pores increases the CO_2.carbon reaction which can develop more pores in the CCAC.

Table 1 Surface area and pore characteristics of samples

Sample	BET surface area (m^2/g)	Mesopores surface area (m^2/g)	Total pore volume (cm^3/g)	Average pore diameter (nm)
Corncob	1.1450	0.4310	0.0021	2.85
CCAC	458.30	265.17	0.2248	3.42

3.1.2 Surface morphology

Figure 2 (a) and (b) shows the morphology of corncob and CCAC, respectively. There was very little pores presence on the surface of the corncob. Once the activation process took place, numerous pores can be seen to appear on the surface of CCAC. Pores development in the char during carbonization was important too because it served as an initiation for pores network formation, which later was enhanced during the activation process.

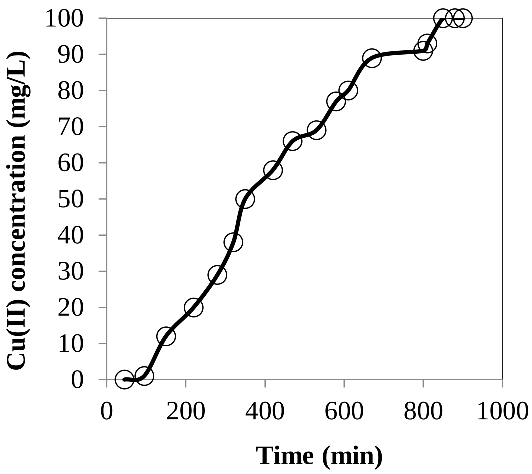


(a) (b)

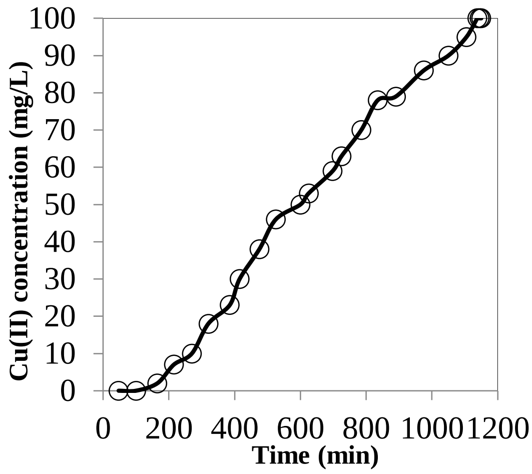
Figure 2 SEM micrographs of (a) corncob and (b) CCAC (magnification 500x)

3.2 Column study

In determining the operation of an adsorption column, two characteristics are important to be studied which is breakthrough time together with the shape of breakthrough curve. Figure 3(a) and b show the breakthrough curve obtained for Cu (II) adsorption on the prepared CCAC for two different bed heights of 4 and 8 cm, respectively, while other parameters such as solution temperature (room temperature), solution pH (original pH) and inlet flow rate (25mL/min) were kept constant. For bed height of 4 and 8 cm, the time taken for them to saturate was 900 and 1150 minutes, respectively. Saturated time is the time when the column is completely saturated and therefore, adsorption no longer occur. At this point, the ratio of C/C_o is 1. The exhaustion period for Cu (II) was greater for bed height 8 cm (1105 min) than 4 cm (800 min).



(a)



(b)

Figure 3 Fixed bed column study for (a) 4 cm bed height and (b) 8 cm bed height

Exhaustion period is the time when the column is about to reach saturation level and the ratio of C/Co is equal to 0.9. It was found that by increasing bed height, the breakthrough and exhaustion time were also increased. This is because, when bed height was increased, the total surface area of adsorbent was increased too. This led to an increment in binding sites for adsorption, thus resulted higher metals uptake capacity and breakthrough time [14]. The removal efficiency for both bed heights showed more than 95%. For 50% breakthrough, the period of 350 min and 600 min for 4 cm and 8 cm bed height, respectively were obtained. This showed that CCAC has a good performance in order to remove Cu (II) from wastewater. Table 2 shows the summary of findings and parameters in column study. As can be seen in Table 2, the volume treated was 22.50 and 28.75 L for 4 cm and 8 cm bed height, respectively. By increasing bed height, mass transfer zone in a column that travels from the entrance of the bed and progressing towards the exit was increased too. Therefore, a longer distance of mass transfer zone was created to get to the exit when the bed height was increased even though if two fixed bed systems were having the same influent concentration. Subsequently, an increase in the mass transfer zone causing an increase in the total volume of treated solution. Adsorption capacity of CCAC in removing Cu(II) was found to be relatively high of 333mg/g. Table 3 shows the comparison of adsorption capacity obtained in this study with other studies.

Table 2 Summary of parameters in column study

Parameters	**Bed height (cm)**	
	4	8
Flow rate (mL/min)	25mL/min	
Concentration (mg/L)	100mg/L	
Exhaustion period (min)	800	1105
50% breakthrough (min)	350	600
Saturation period (min)	900	1150
Volume treated (L)	22.50	28.75

Table 3 Comparison of adsorption capacity

Precursor	**Adsorbate**	**Adsorption capacity (mg/L)**	**References**
Corncob	Cu(II)	333.00	This study
Honeydew	Cr(III)	834.94	[9]
	Zn(II)	326.19	
Elm tree waste	Pb(II)	232.56	[15]
	Cr(VI)	113.63	
Walnut shell	Cr(III)	792.00	[16]
	Pb(II)	638.00	
	Cd(II)	574.00	
	Cu(II)	345.00	
Opuntia ficus-indica	Cu(II)	49.00	[17]
	Ni(II)	44.00	
Ulva lactuca	Cu(II)	84.70	[18]
	Cd(II)	84.60	
	Cr(III)	82.00	
	Pb(II)	83.30	

4. CONCLUSION

Corncob was successfully converted into CCAC and posed relatively high BET surface area (458.30 m^2/g) and adsorption capacity of 333 mg/g. The Cu(II) removal was revealed to be higher when bed height increased. The exhaustion period for Cu(II) was greater for bed height 8 cm (1105 min) than 4 cm (800 min). For 50% breakthrough, the period showed that 350 min and 600 min for 4 cm and 8 cm bed height, respectively. By using 4 cm and 8 cm of bed height, time taken to reach saturation level were 900 and 1150 minutes, respectively. The removal efficiency for both bed heights showed more than 95% for concentration of 100mg/L. The volume of solution treated was also found to increase with the increased of bed height. Corncob was proven to be a good precursor as an AC to remove Cu(II).

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