

Preparation of Activated Carbon from Corn Cobs for Multiple Adsorption of Heavy Metal Ions in Aqueous Solution

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ABSTRACT

In this study batch adsorption of different heavy metal ions (Nickel, Copper, Zinc, Lead, Cadmium and Chromium) in aqueous solution using activated carbon from Corn cobs was investigated. The Corn cob was carbonized between 300^oC - 400^oC, and activated at 800^oC using nitric acid. The iodine number, methylene adsorption, bulk density, Benzene adsorption, and ash content of the Corn cob activated carbon produced compared well with commercial carbons. Textural and surface characteristics of CCAC was determined by XRD, FTIR and SEM. Multiple adsorption of these metals in same aqueous solution using Corn cob carbon showed that adsorption capacity is in the order Pb>Cd>Cu>Zn>Ni>Cr which showed that these metal ions can be adsorbed selectively by Corn cob activated carbon. The order of adsorption is related to the maximum adsorption of lead, cadmium, copper on Corn cob was found to be in the order of ionic radius of the heavy metals used. Therefore this study confirmed that Corn cob can serve as a good source of activated carbon with multiple metal ions – removing potentials and may serve as a better replacement for commercial activated carbons in applications that less expensive adsorbents for the elimination of heavy metal ions from industrial waste water.

Key Words: Activated Carbon, Multiple adsorption, Heavy metals, Corn cob.

I. INTRODUCTION

In recent years, the demand for safe and economic methods for removing heavy metals from industrial waste water has required research to produce low-cost commercially available activated carbon. Unlike organic pollutants mostly susceptible to biological degradation, heavy metal ions do not degrade to harmless end products. Heavy metals such as Chromium, Cadmium, lead, Copper, Zinc and Nickel often found in industrial waste waters are carcinogenic or toxic to the environment [1]. The low cost agricultural waste by-products such as sugarcane bagasse, rice husk, sawdust, coconut husk, oil palm shell, Neembark, Zeolite-primarily based oil shale ash and many others used for the elimination of heavy metals from waste water have been investigated by way of numerous researchers [2-5].

Most of the early works reported are on single, double, and triple metal ion adsorption. Although some other works, carried out by Kermit, et al., and Myroslav et al., [6,7], using activated carbon made from peanut shells and; raw and activated clinoptilolite showed that selective metal ion adsorption of copper, lead, cadmium, zinc and nickel is possible in same aqueous solution. Uzun and Guzel et al. also

determined that the rate of uptake of Cu^{2+} , Mn^{2+} , Fe^{2+} and Ni^{2+} using three adsorbents (Chitosan, Agar and a commercial carbon, Merck 2514) are different and concluded that an adsorbent that adsorb one adsorbate may not be capable to adsorb another adsorbate, effectively [8]. In the work of Bassam et al., the adsorption capacity of Cd(II), Ni(II), Zn(II) onto geopolymers decreases with competition in a similar manner to the adsorption of metal ions onto zeolite. However, the adsorption of Cu(II) onto geopolymers increases with competition like adsorption of metal ions onto kaolinite hence the need to study the multiple adsorption of these metal ions often found in industrial waste water [9]. The review from previous works carried out on Corn cob activated carbon showed that equilibrium study on multiple batch adsorption of different heavy metal ions from aqueous solution using activated carbon from Corn cobs is yet to be investigated for these six metals i.e. Chromium, Cadmium, lead, Copper, Zinc and Nickel, often found in industrial waste waters. Therefore, the objectives of this research is to study the multiple and competitive adsorption of these metals in aqueous solution using activated carbon from Corn cob and develop empirical models that can be used to pretend the sorption process. In present work, activated carbon was prepared from Corn cob by nitric acid activation was chosen as a natural and a promising alternative due to its abundance and its low cost commercial value.

II. MATERIALS AND METHODS

2.1 Materials

The raw materials used for this study are as follows: Granular activated carbon produced from Corn cob, distilled water, Nitric acid, metal salts of Nickel, Copper, Zinc, Cadmium, Lead and Chromium, Methylene Blue, Sodium Thiosulphate and Iodine solution (for characterization of carbon). Industrial waste water collected after treatment to analyze heavy metal ions presence. Other equipments and apparatus used for the research are: An analytical weighing Balance, pyrolyzer with condenser, Electric burner, Measuring cylinder, Heating mantle, Desiccators, Crucibles, Funnels and filter paper, Digital weighing Balance, Mortar and pestle, pH meter, Spatula, Burette and retort stand, Beakers, conical flasks, stirrer Muffle furnace, Set of sieves (1.18mm, 600 μm , 300 μm , 150 μm , 75 μm), Cutting machine and oven, Atomic Absorption Spectrophotometer (AAS).

2.2 Preparation of Corn cob Samples

The Corn cob was cut into small sizes of about 2cm long with a cutting machine. After the cutting, pieces of Corn cob were washed thoroughly with distilled water to remove all the adherent extraneous matter. The Corn cob was then dried in the oven.

2.3 Carbonization Process

100 g of Corn cob pieces were weighed into a reactor. The Corn cob was pyrolysed between (300–400 $^{\circ}\text{C}$) in the absence of air for two hours [10]. The distillate formed during the pyrolysis was collected by the receiver connected to a condenser. The charred material was cooled at room temperature before discharging it into container.

2.4 Chemical Activation

The carbonized material was crushed. The crushed sample was screened using 1.18mm sieve in order to get a uniform size of the particle. 10 g of carbonized Corn cob was carefully weighed and put in beaker containing 150cm³ of Nitric acid. The solution was stirred until the mixture formed a paste. The paste was allowed to pass through an oven in order to reduce the moisture content. The crucible was then transferred into a muffle furnace where it was heated for 1hour at a temperature of 800 °C in the absence of air so as to increase the surface area to volume ratio of the sample for proper adsorption. After heating, it was cooled at room temperature and was washed with distilled water until the pH value was approximately 7, showing no trace of nitric acid. After washing, the activated carbon was then dried and the final products are kept in an air tight containers . The same procedure was repeated using with different concentrations of Nitric acid (0.025M - 0.5M). Nitric acid was found to be the best for metal ion adsorption and so was used as previously reported by Ademiluyi and David-West,E.O. et al.[11].

2.5 Characterization of Activated Carbon Produced

The characterization of the activated carbon involves the determination of properties such as bulk density, pore volume, percentage burnt off, moisture content, ash content, particle size, benzene adsorption, methylene blue and iodine number [10].

The specific surface areas of AC produced by the optimum conditions was determined by the BET method using nitrogen as the adsorbate at 77K utilizing the commonly used Autosorb instrument. Prior to the measurements, the samples were out gassed at 300°C under nitrogen for at least 12h. Nitrogen adsorption isotherms of AC and char were tested over a relative pressure (P/P^0) range from 10^{-7} to 1. The total pore volumes were estimated to be the equivalent liquid volume of the adsorbate (N₂) at a relative pressure of 0.99. The BET surface of the samples was calculated by the Brunauer-Emmett-Teller (BET) equation.

2.5.1 X-ray diffraction spectroscopy

X-ray powder diffraction (XRD) patterns of the Corn cob activated carbon was recorded on a Rigaku Miniflex (Rigaku Corporation, Japan) X-ray diffractometer using Ni filtered CuK α radiation ($\lambda = 1.5418 \text{ \AA}$) with a scan speed of 2° min^{-1} and a scan range of 10-80° at 30 kV and 15 mA.

2.5.2. Fourier Transform Infrared Spectroscopy (FTIR) Analysis

Chemical characterization of functional groups was detected by Fourier transform infrared spectrometer (FTIR-100, Perkin Elmer) in the scanning range of 4000–400 cm⁻¹ . The adsorbent and potassium bromide (KBr) were dried in an oven and then ground together in a ratio of 20:1 (KBr:AC) for FTIR measurement using disc sample method.

2.5.3 Scanning Electron Microscopy (SEM) Analysis

In order to reveal the surface morphologies of the samples under investigation in this study, scanning electron micrographs of activated carbon prepared from Corn cob (CCAC) were obtained using a

Quanta-200F field-emission scanning electron microscope (FE-SEM) operated at 1-20 kV with an energy dispersive spectrometer (EDS) attachment. Because the SEM utilizes vacuum conditions and uses electrons to form an image, special preparations must be done to the sample.

2.6 Determination of Adsorption Capacity

Six metal ions (Cd^{2+} , Ni^{2+} , Pb^{2+} , Cr^{3+} , Cu^{2+} and Zn^{2+}) often found in industrial waste waters were used for this study. Different concentrations of these heavy metals ions in solution were prepared. Batch adsorption of the six metal ions onto Corn cob activated carbon was carried out in the same aqueous solution for the different concentrations of these heavy metals ions in solution i.e. 100ml of the six metal ions in solution : 1g of activated carbon . each sample was stirred, and adsorption was carried out for 30, 45, 90, 120, 240 and 990 minutes till equilibration. After each time interval the sample was filtered out with filter paper to remove any carbon particles. This process was repeated for different concentrations of these heavy metals ions in solution. 5 ml of the resulting filtrate from each sample was diluted with 50ml of 2 % nitric acid and metals ions in filtrate after digestion were analyzed using Atomic Absorption Spectrophotometer (AAS).

2.7 Metal Uptake

The amount of metal ions adsorbed by the adsorbent was evaluated using equation(1)

$$q_t = \frac{(C_0 - C_t)v}{w} \dots\dots\dots(1)$$

The amount of metal adsorbed per unit weight of adsorbent, q_e (mg/g), was calculated from equation 2 [12].

$$q_e = \frac{(C_0 - C_e)v}{w} \dots\dots\dots(2)$$

Where, C_0 and C_t are the initial and final concentrations of the heavy metals present in waste water before and after adsorption, for a period of time t (mg/L) respectively: C_e represent the concentrations of heavy metals in waste water (mg/L) when equilibrium was attained: the volume of waste water used is represented by V (ml): while W represent the mass (g) of the adsorbent used. The percentage of metal ions removed was obtained from equation[13] (3):

$$R(\%) = \frac{(C_0 - C_t) \times 100}{C_0} \dots\dots\dots(3)$$

Where (R %) is the ratio of difference in metal concentration before and after adsorption.

III.RESULTS AND DISCUSSION

3.1 Characterization of Activated Carbon from Corn cob

The work of Ademiluyi and David-West,E.O. et al [11] on effect of chemical activation on the adsorption of heavy metals using activated carbon from waste materials revealed that waste Corn cob activated with HNO_3 effectively remove metal ions from waste streams and in different metal recovery processes than other activating agent. Hence different concentration of Nitric acid was initially prepared and used for activation in this study. Iodine Number is a measure of micro-porous structures of the activated carbon which shows the degree of porosity of Corn cob carbon and Benzene adsorption is a measure of meso-pore content of activated carbon. The higher the Benzene adsorption capacity, the

higher the degree of adsorption hence these two parameters were used to determine the best concentration of Nitric acid to be used for activation. Fig-1 shows a plot of Iodine Number and Benzene adsorption capacity of the activated carbon produced against concentration of activating agent. The Iodine number of carbon produced was highest at 0.1 M concentration of Nitric acid. Also Benzene adsorption capacity plotted against different concentration of activating agent in Fig-1, showed that as concentration of the activating agent used to activate the carbon increased, the amount of benzene adsorbed also increased to a maximum value at 0.1 M of Nitric acid. Benzene adsorption capacity decreased to a minimum value at Nitric acid concentration of 0.025 M. Hence the activated carbon used for the adsorption of the heavy metal ions in this study was activated using 0.1M Nitric acid. Table-1 shows the characterization of activated carbon of the Corn cob used for the batch adsorption of Nickel, Copper, Zinc, Lead, Cadmium, and Chromium ions in solution compared with reference activated carbon. Moderate bulk density, favours better adsorption and from Table-1, the bulk density falls within the reference standard. The Methylene Blue adsorptive capacity which is a measure of meso-pore content of the activated carbon also falls within the reference standard. The higher the Iodine Number, (a measure of activity level and the micro pore content of the activated carbon; higher number indicates higher degree of activation) the higher the degree of adsorption. The ash content obtained after activation, compares favourably with reference activated carbon. Adsorption is more favored when ash content is neither too high nor too low.

Table-1 Characterization of Activated Carbon from Corn cob

S.No	Parameters	Local Corn cob	Reference Standards (Activated Carbon)
1	Bulk Density	0.469	0.2-0.6 [14]
2	Iodine number	1,162	500-1200 [14]
3	Ash content	3.8	≤8 [15]
4	Methylene-Blue adsorptive capacity	938.46	900-1100
5	Benzene adsorptive capacity	146.3	129 [10]

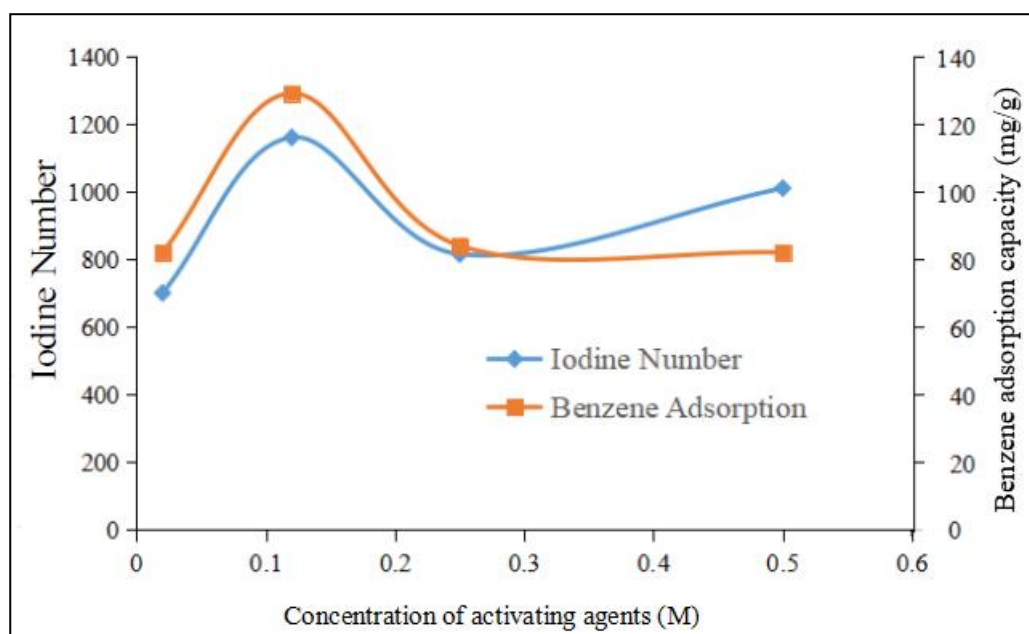


Fig. 1 Characterization of Activated Carbon from Corn cob Showing Benzene adsorption Capacity and Iodine number using different concentration of Nitric acid.

3.2. Textural and surface characterization of CCAC

Detailed characteristics of the porosities of CCAC and that of carbonized char were summarized in Table-1. The total pore volume was estimated by converting the amount of N₂ gas adsorbed at a relative pressure of 0.95 to equivalent liquid volume of the adsorbate (N₂). The mesopore volume was determined by subtracting micropore volume from the total pore volume. From Table-1, it was evident that the micropores of CCAC account about 72% of the total pore volume, with a well developed porous structure. The micropore volume, external surface area and micropore surface area that deduced from the t-method were tabulated in the same table. In the present study, it can be found that the BET surface area, Langmuir surface area, and total pore volume of CCAC were greatly improved compared to char, implying development of additional pores during the microwave irradiation stage [16-18].

Table-2. Porosity structures of CCAC and carbonized char.

Properties	Corn cob Activated Carbon (CCAC)
BET surface area (m ² /g)	873
Micropore surface area (m ² /g)	742
External surface area (m ² /g)	624
Langmuir surface area (m ² /g)	916
Total pore volume (cm ³ /g)	0.46
Micropore volume (cm ³ /g)	0.34
Mesopore volume (cm ³ /g)	0.15
Average pore size (A ⁰)	26.2

3.3 Concentration of Metal ions (mg/L) in Industrial Waste Water Before and After Adsorption

Industrial waste water used for this research was obtained from the effluent discharge point of electroplating section of the Porus Drugs & Intermediates to expand its bulk drug unit and still has a conductivity of 82 μ S. Hence the metal ions in the waste water from the effluent drug plant was analyzed before and after treatment with Corn cob activated carbon. In Fig 2, the concentration of metal ions mg/L was plotted against metal ions in industrial waste water before and after adsorption.

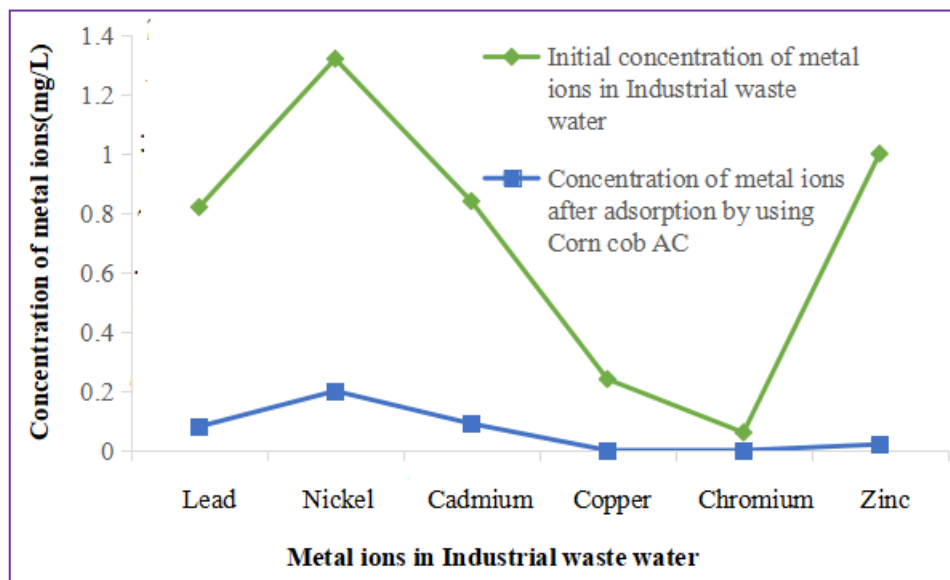


Fig. 2 Concentration of metal ions mg/L in industrial waste water before and after adsorption

The concentration of these heavy metal ions was high before adsorption from the treated industrial waste water as shown in Figure 2. Lead, Nickel and Cadmium in industrial waste water before adsorption was higher than the quantity required by WHO while the concentrations of Chromium, Copper and Zinc in industrial waste water before adsorption were below the concentration required by World Health Organization. The concentrations of metal ions after adsorption with Corn cob carbon reduced drastically. In fact Copper and Chromium were adsorbed completely, which shows the effectiveness of activated carbon from Corn cob. The results also showed that Corn cob activated carbon adsorb metal ions in same aqueous solution competitively or selectively. After adsorption with Corn cob activated carbon, the amount of metal ions available was too small to study the adsorption until equilibrium is reached because the industrial waste water was already treated. Hence metallic salts containing these metal ions were used for the study.

3.4. The XRD Analysis of Corn cob Activated Carbon

Fig-3 is the XRD patterns of Corn cob activated carbon. As shown in Fig-3, the strong diffraction peaks emerged at $2\theta=25^\circ$, $2\theta=45^\circ$, respectively. This result indicates the existence of graphite crystallite in Corn cob activated carbon. The diffraction peaks of commercial activated carbon are sharper than those of Corn cob activated carbon, indicating that crystallite size of Corn cob activated carbon is smaller. This result can be proven by the data of Table-2. The whole wall of activated carbon is composed of graphite crystallite scale decreases, which can lead to widening or internal structure disordered, so as to form a larger specific surface area. The activated carbon is comprised of ultrafine particles possesses porous structure. The lower the crystallinity, the larger the specific surface area. This

Corn cob activated carbon very good adsorbent for adsorption of heavy metals in industrial waste water.

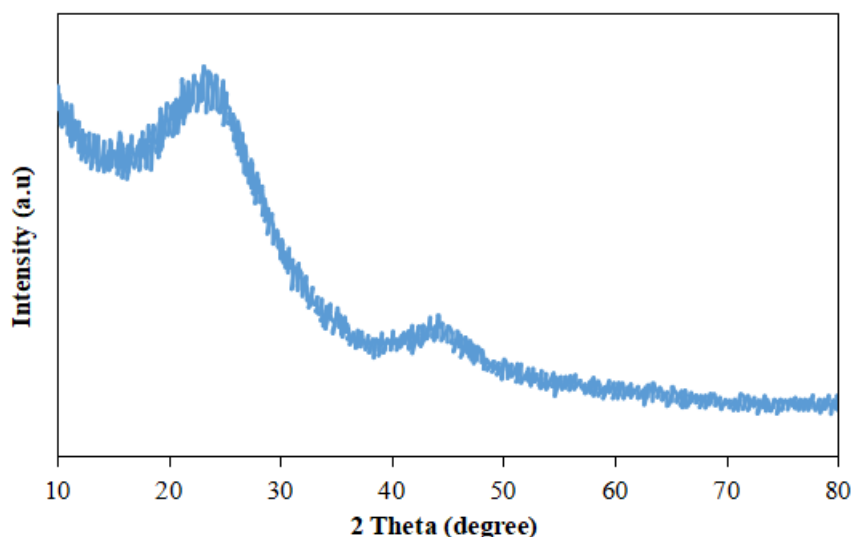


Fig-3: XRD patterns of Corn cob activated carbon

Table-3: Crystalline parameters of activated carbon

Samples	Microcrystalline diameter La/nm	Microcrystalline thickness Lc/nm	d ₀₀₂ /nm	d ₁₀₀ /nm
Corn cob Activated carbon	2.7632	0.7539	0.3479	0.2047
Commercial Activated carbon	3.7916	0.9824	0.3326	0.2146

3.5. The FT-IR Analysis of Corn cob Activated Carbon

FTIR spectroscopy was used to investigate the functional groups present in Corn cob activated carbon. The FTIR spectra of activated carbon prepared from corncobs was shown in Fig.4. It is seen that the absorbance bands were observed to have peaks at 3441.6, 2920, 1627.7, 1346.6, 1120.8, 1053.3 cm^{-1} . Most of these bands have been reported by other investigators for different carbon materials. The band at around 3441.6 cm^{-1} can be assigned to the -OH stretching vibration mode of hydroxyl functional groups [19]. The broad absorption at 2920 cm^{-1} is attributed to the C-H stretching [20]. The peak at 1627.7 cm^{-1} the characteristics of the C-O stretching vibration of lactonic and carbonyl groups [21]. The peaks occurring at 1346.5, 1120.8 and 1053.3 cm^{-1} are all ascribed to oxygen functionalities such as highly conjugated C-O stretching, C-O stretching in carboxylic groups, and carboxylate moieties [18]. A weak absorption at 898 cm^{-1} was the characteristic of β -glycosidic linkages [22].

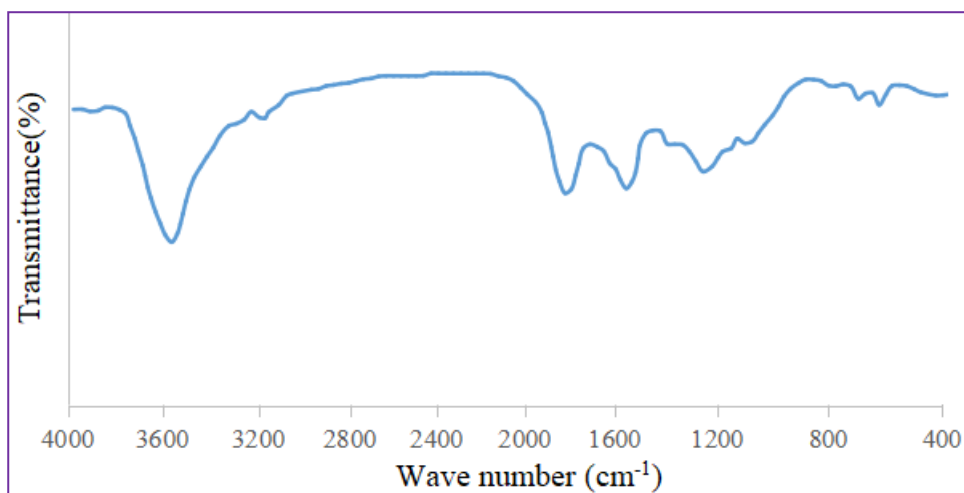


Fig-4 : FTIR spectra of Corn cob activated carbon

3.6 Surface Morphology

Scanning Electron Microscope (SEM) was used to observe the pore structure of the activated carbon. Pores present in activated carbon act as the active sites, where adsorption takes place. The Scanning Electron Microscope images of activated carbon produced from Corn cob activated using zinc chloride ($ZnCl_2$) are shown in fig-5 and fig-6 at 31 and 200 magnifications. SEM photograph showed that wide varieties of pores are present in the activated carbon which is more visible at 200 magnifications.

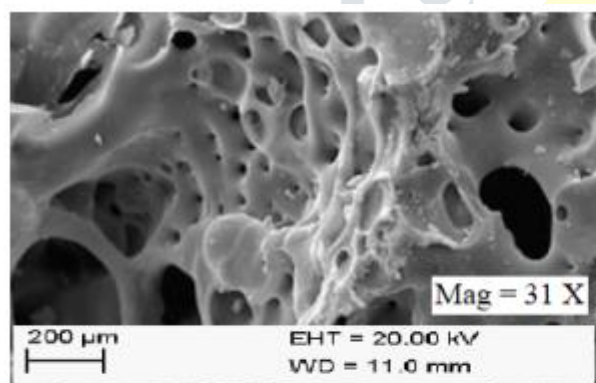


Fig. 5. SEM image of activated carbon from Corn cob using zinc chloride ($ZnCl_2$), at 31 ×

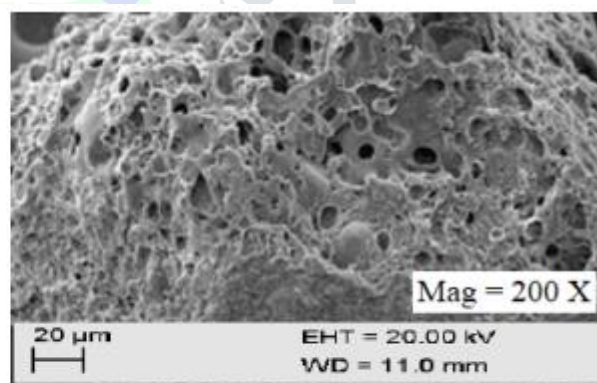


Fig. 6. SEM image of activated carbon from Corn cob using zinc chloride ($ZnCl_2$), at 200 ×

3.7 Quantity of Adsorbate adsorbed at equilibrium against equilibrium concentration

Fig-7 shows the quantity of adsorbate adsorbed at equilibrium against equilibrium concentration. The quantity of heavy metal ions adsorbed increased with increase in concentration of adsorbate. Since the activated carbon used is a micro porous adsorbent, heavy metals penetrate easily into these pores as the concentration of these metal ions increased. The amount adsorbed also increased until the pores were saturated where the adsorbates can no longer be adsorbed at the pores. Similar behavior was observed by Zacaria, et al.[23], during the study of the adsorption of several metal ions onto a low-cost biosorbent. As shown in Fig. 3 high amount of Lead, Cadmium, Copper and were adsorbed at the same

time than Nickel, Zinc, and Chromium. This is an indication that Corn cob activated carbon has more affinity for some metals than others.

It was also observed that the rate of adsorption of Copper and zinc were close, yet Corn cob activated carbon was able to adsorb them separately in same aqueous solution.

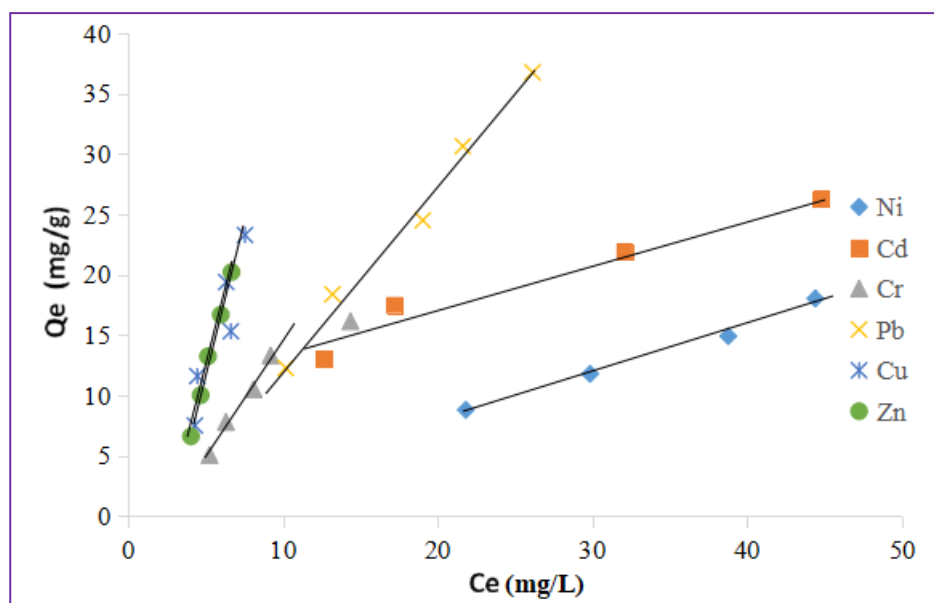


Fig-7 Quantity of Adsorbate Adsorbed at Equilibrium against Equilibrium Concentration

3.8 Rate of Multiple Adsorption of Heavy Metal ions using Activated Carbon from Corn cob in aqueous solutions of Different Concentrations

Fig-8 shows the amount of heavy metal ions adsorbed (Q_e) in mg/g of carbon at different adsorption times for the different metal ions in aqueous solution using 166 mg/L of each metal ions from the metallic salts in aqueous solution. The amount of heavy metal ions adsorbed differ for different metal ions in solution. Each of the heavy metal ions exhibited some level of desorption before attainment of equilibrium at about 240 minutes. At the initial stage, the rate of removal of the metal ions was higher, due to the availability of more active sites on the surface of the carbon and became slower at later stages of contact time, due to the decreased or lesser number of active sites. Similar results have been reported for the removal of dyes organic acids and metal ions by (Kannan and Veemaraj, 2009)[24].

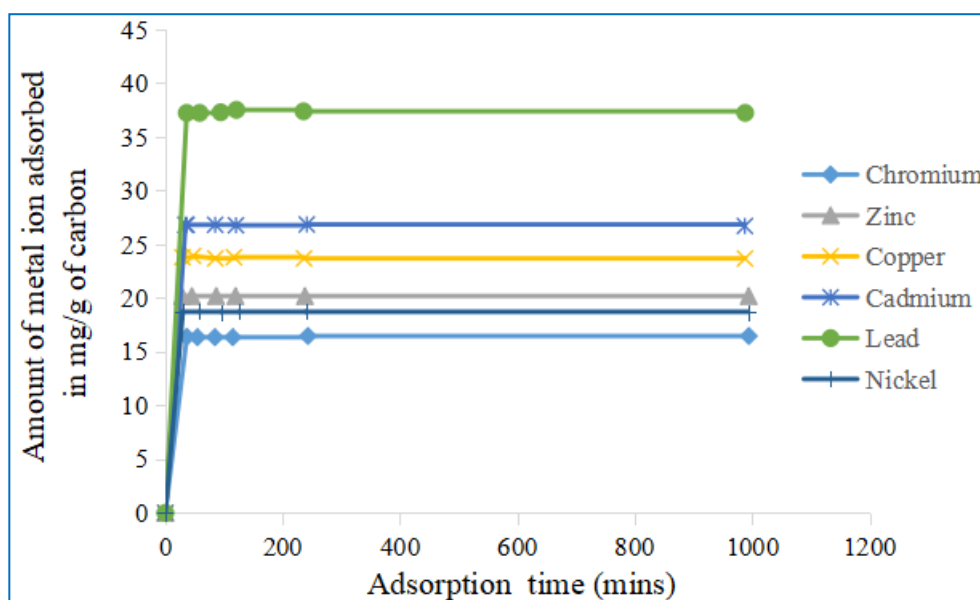


Fig-8 Amount of heavy metal ion adsorbed in mg/g of carbon at different adsorption times for the different metals ions in aqueous solution (166 mg/L of each metal salt in aqueous solution).

This is an indication that the multiple adsorption of heavy metal ions is time dependent. The uptake rate is controlled by the rate at which the adsorbate is transported from exterior to the interior sites of the adsorbent particles. Fig-8 also shows how these metal ions are adsorbed selectively at same time interval. The amount of metal ions adsorbed also differs though the metallic salts added before adsorption was the same. Using same concentration of adsorbate, Lead, Cadmium and Copper are more adsorbed than Zinc, Nickel and Chromium i.e. $Pb > Cd > Cu > Zn > Ni > Cr$. This shows that Corn cob can be employed effectively in batch adsorption of different heavy metal ions in aqueous solution.

The work of Ingmar[25] on hydrated metal ions in aqueous solution shows that the M–O bonds are mainly of electrostatic character, the coordination number of the hydrated metal ions is expected to be determined by the ratio of the ionic radius of the metal ion and the radius of the water oxygen atom ; the size of the water oxygen atom at coordination to metal ions has been determined to be 1.34 Å. It is therefore expected that metal ions with an ionic radius smaller than 0.55 Å is expected to be tetrahedral, metal ions with an ionic radius in the range 0.55–0.98 Å are expected to be octahedral, while metal ions with an ionic radius larger than 0.98 Å are expected to be eight-coordinate or have an even higher coordination number. This principle can be used to explain why Lead and Cadmium ions were more adsorbed by Corn cob activated carbon than other metals.

Table-3 Overview of Aqua complex of metal ions and its adsorption in aqueous solution.

S.No	Aqua complex of metal ions adsorbed	Amount of metal ions in 166 mg of metallic salt/liter of aqueous solution before adsorption (mg/L) from present study
1	$Pb(H_2O)_6^{2+}$	132.19
2	$Cd(H_2O)_6^{2+}$	93.82
3	$Cu(H_2O)_6^{2+}$	81.73
4	$Zn(H_2O)_6^{2+}$	72.40
5	$Ni(H_2O)_6^{2+}$	69.36
6	$Cr(H_2O)_6^{2+}$	57.33

As reported by Ingmar [25], the expected coordination figure for four-coordination is therefore the tetrahedron, for six-coordination the octahedron, for eight-coordination the square anti-prism and for nine-coordination the tricapped trigonal prism in which these metals ions used in these display in solution as shown in Fig-9. The porous nature of Corn cob carbon make it easy for these competitive adsorption and the structure of these metal ions in solution makes bonding of these metals to the pores of Corn cob carbon easier.

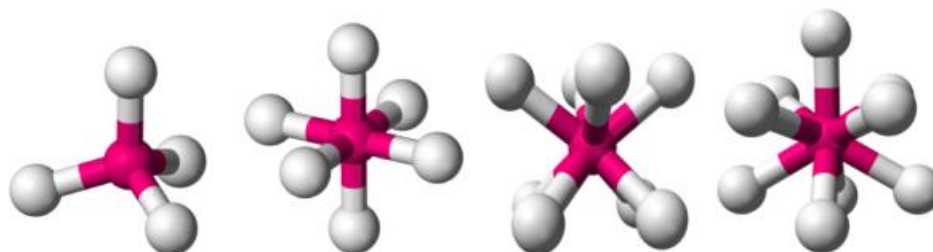


Fig-9. Basic models for tetrahedron, octahedron, square antiprism, and tricapped trigonal prism.

The work of Chen et al. [26], while studying the adsorption of aqueous Cd^{2+} , Pb^{2+} , Cu^{2+} ions by nanohydroxyapatite also similarly reported that the sorption affinity of nano-HAP for Pb(II) is always higher than that for Cu(II) and for Cd(II); the sorption maxima for the Cd, Pb and Cu follow the order $\text{Pb}^{2+} > \text{Cu}^{2+} > \text{Cd}^{2+}$, which they reported could be inversely proportional to the hydrated ionic radii as Pb^{2+} (4.01 Å) > Cu^{2+} (4.19 Å) > Cd^{2+} (4.26 Å). The amount of activated carbon adsorbed also increased with time until equilibrium was attained when higher metallic ion concentration of 500 mg/L of each metals salts in solution was used for adsorption and also more surface sites were covered as shown in Fig-10. It was observed that heavy metal ions are being adsorbed according to this order $\text{Pb} > \text{Cd} > \text{Cu} > \text{Zn} > \text{Ni} > \text{Cr}$. According to this order, chromium (Cr) was the least adsorbed and Pb was the most adsorbed, because the heavy metal whose complex is stable will be present in the complex at higher levels and this will cause the complex to be adsorbed more [8]. The capacities of the adsorbent get exhausted due to nonavailability of active surface sites. It was also observed from Fig-10, that the amount of metal ions adsorbed, rapidly reached equilibrium from 120min before it became stable. Using higher concentration of adsorbate, (500 mg/L) there exist closeness in the amount of Copper and Cadmium adsorbed as well as the amount of Chromium and Nickel adsorbed. This difference can be attributed to the stability of these metallic complexes at higher concentration as compared with what happened at lower concentration in Fig-8.

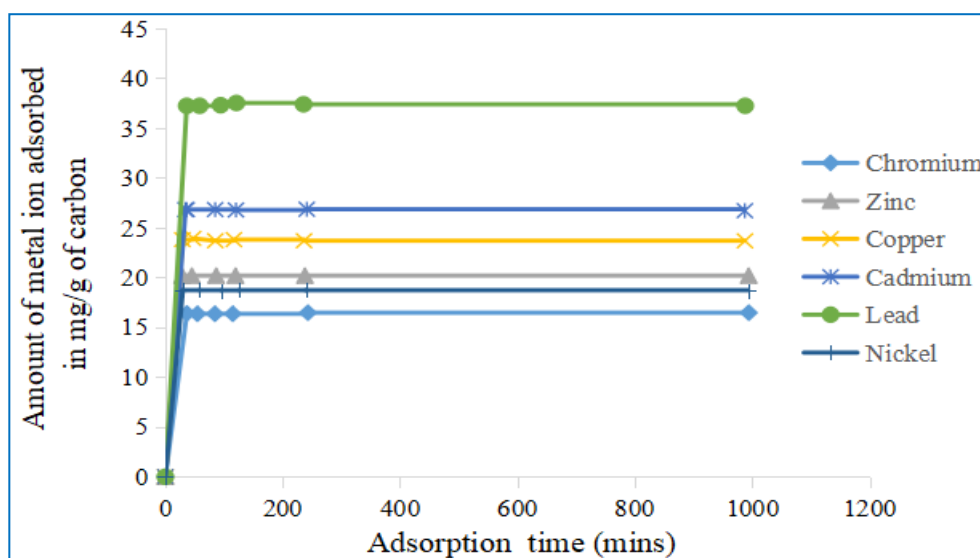


Fig-10 Amount of heavy metal ion adsorbed in mg/g of carbon at different adsorption times for the different metal ions in aqueous solution (500 mg/L of each metal salt in aqueous solution).

IV.CONCLUSION

Multiple batch adsorption of different heavy metal ions in aqueous solution using activated carbon from Corn cob has been investigated. The results obtained from equilibrium study on batch adsorption of these heavy metal ions showed that Corn cob activated carbon can effectively be adopted in multiple adsorption of these heavy metal ions when present in waste water. An increase in contact time resulted in increase in the quantity of metal ions adsorbed till equilibrium was reached. It can also be seen that heavy metal ions are adsorbed in the following affinity order of adsorption $Pb > Cd > Cu > Zn > Ni > Cr$. Lead ions was the most adsorbed and Nickel ions the least adsorbed in the same aqueous solution. The order of adsorption is related to the maximum adsorption of lead, cadmium, copper on Corn cob was found to be in the order of ionic radius of the heavy metals used. The high multiple adsorption intensity of activated carbon from Corn cob and its high affinity for metal ions of Nickel, Copper, Zinc, Lead, Cadmium, and Chromium can help resolve many adsorption challenges in the industry and in water purification processes. This research work on multiple adsorption of different heavy metal ions in an aqueous solution using activated carbon from Corn cob has also contributed to the search for less expensive and easily available material for adsorption and separation process.

V.ACKNOWLEDGEMENT

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