

Adsorption of Copper (II) Ions from Aqueous Solution onto Activated Carbon Prepared from Cane Papyrus

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ABSTRACT: The present study evaluates the suitability of activated carbon, prepared from Cane Papyrus, a plant that grows naturally and can be found quite easily, which serves as a biological sorbent for removal of Cu^{2+} ions from aqueous solutions. Fourier transform infra-red analysis for the activated carbon, prepared from Cane Papyrus confirms the presence of amino ($-\text{NH}$), carbonyl ($-\text{C}=\text{O}$), and hydroxyl ($-\text{OH}$) functional groups with Bath mode getting used to investigate the effects of the following parameters: adsorbent dosage (among the rates of 10, 20, and 30 g/L), pH values, Cu^{2+} initial concentration, and contact time. Results reveal higher efficiency (98%) of powdered adsorbent for removal of Cu^{2+} ions, which is found at $\text{pH}=6$ with 30 g/L activated carbon, prepared from Cane Papyrus, for a duration of 2 hours. The Freundlich isotherm model with linearized coefficient of 0.982 describes the adsorption process more suitably than the langmuir model, in which this rate equals to 0.899. Pseudo-second order kinetic equation best describes the kinetics of the reaction. Furthermore, it has been found that 0.5M HCl is a better desorbing agent than either 0.5 M NaOH or de-ionized water. The experimental data, obtained, demonstrate that the activated carbon prepared from Cane Papyrus can be used as a suitable adsorbent for Copper(II) ion removal from aqueous solutions.

Keywords: Natural Plants, Biosorbent, Activation, Removal Efficiency, Kinetics.

INTRODUCTION

Heavy metal pollution has been one of the most challenging environmental problems due to its toxicity, persistence, and bioaccumulation tendencies (Delaila et al., 2008). Most industries produce and discharge metal-containing wastes mostly into water bodies, which affect the aesthetic quality of the water, while increasing the concentration of present metals (Donohue, 2004). Activities such as mining and smelting operations, wastewater treatment facilities, various agricultural works, and metal casting contribute significantly to the

concentration of heavy metals in the environment (Delaila et al., 2008; Patil et al., 2012)). Heavy metal contamination is not a recent problem, though its management and prevention is still a global concern. Examples of involved heavy metal ions include Cd^{2+} , Cr^{6+} , Cu^{2+} , Hg^{2+} , Ni^{2+} , and Pb^{2+} . Elevated concentrations of heavy metals are toxic for living organisms. For instance, high concentrations of Cu^{2+} can cause diseases like bone deformation, extra cholesterol intake, and anemia (Mukesh & Thakur, 2013). The allowable amount of copper is 2 mg/L, according to the European Union standards (Dorris et al., 2000).

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Several techniques have been designed for removal of heavy metals from aqueous solutions, including ion exchange, chemical precipitation/co-precipitation, filtration, coagulation, membrane technologies, and commercial activated carbon (Inglezakis et al., 2004; Baccar et al., 2009). The major disadvantages of these methods lie in the cost involved, the efficiency of the processes, and disposal of wastes generated (Alatabe, 2012; Cheung et al., 2001). Technologies that treat Cu^{2+} contaminated waters include (i) adsorption both in batch and column operations (Moselhy et al., 2017; Hameed et al., 2007), (ii) coagulation, electro coagulation, and flocculation, (iii) ion exchange (Veli & Pekey, 2004), and (iv) membrane filtration (Bouhamed et al., 2016). Convenient design and operation has rendered adsorption in packed beds the most applicable practice among all these technologies, particularly within a frugal approach (Zhu et al., 2012). Adsorption processes are able to eliminate many contaminants in a multi-barrier approach. There is a growing interest in the application of plant biomass for water treatment in general and aqueous Cu^{2+} removal in particular (Futalan et al., 2011; Vernersson et al., 2002). The main advantage of plant biomass is that it is readily available and can work under almost-neutral pH (Lin & Wang, 2002). The contaminant removal mechanism by this class of material is not established. It is currently understood that the driving force for decontamination relies in its affinity with several species, present in the biomass structure (e.g. cellulosic groups of Ca^{2+} , Mg^{2+} , OH^- , and $-\text{NH}_2$,) (Prasad et al., 2008). Relevant removal mechanisms include bio sorption, ion-exchange, and physical adsorption (Qin et al., 2006; Hanzlik et al., 2004). In recent years, several plant materials have been positively tested for Cu^{2+} removal such as (i) cinnamomum camphora (Chen et al., 2010)

and (ii) modified barley straw (Pehlivan et al., 2012). The literature review indicates that Cane Papyrus is yet to be used for Cu^{2+} removal from industrial waste water.

Therefore, this study presents the use of Cane Papyrus as a potential, novel, environmentally-friendly, and cheap adsorbent for elimination of Cu^{2+} ions from aqueous solution and wastewater samples. Usually industries seek out low cost methods for waste water treatment, hence they may option for low cost adsorbents. Although research reports show varieties of low cost adsorbents, all adsorbents are not available easily throughout the world (Alatabe, 2018).

The objective of the present study is to prepare activated carbon from can papyrus in order to increase the removal efficiency of the metals via adsorption, then to investigate the adsorption potential of activated carbon, prepared from Cane Papyrus in the removal of Cu^{2+} ions from aqueous solution, while investigating the effects of pH, adsorbent amount, contact time, and concentration of metal ions in the solution. The langmuir and Freundlich isotherms models are used to investigate equilibrium data. The adsorption mechanisms of Cu^{2+} ions onto activated carbon, prepared from Cane Papyrus, are also evaluated in terms of kinetics and thermodynamics.

MATERIALS AND METHODS

Adsorbent Cane Papyrus was collected from farmlands in Al-Amarah Marshes (Al Hawiseh Marshes) south of Iraq, as shown in the maps below Figure 1 (Geographic Location, 2013). Collecting process started in March 2017, in this time the leaves of Cane Papyrus had already been grown and seemed very fresh. The leaves were carefully detached from the plant stems and washed thoroughly with tap water to remove dirt, soil particles, and debris, then to get sun-dried for 10 days.



Al Hawiseh Marshes

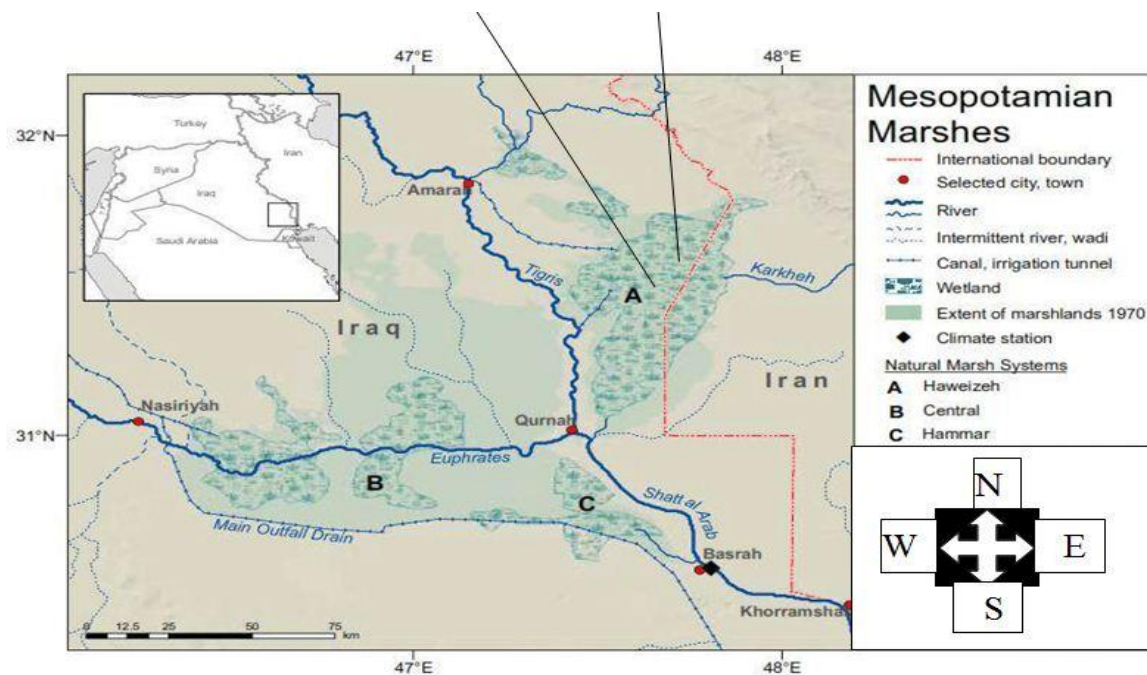


Fig. 1. Map of the marshes, south of Iraq

The dry biomass was ground to fine powder, using a hammer mill, and then weighed. After milling, the materials got dried in an oven at 105 °C for 24 h. To avoid further moisture absorption, samples were preserved in desiccators. Dried samples were then taken in a porcelain crucible and covered with lid to be placed in control muffle furnace at 750 °C for an hour. Afterwards, the carbonized cane papyrus samples got cooled and treated with alkali solution (sodium hydroxide) for its resultant leaching ash. After removal of ash from cane papyrus char, the char was washed and dried in oven. Two grams (2 g) of treated cane papyrus char was soaked in zinc chloride solution for 24 h (Cheung et al., 2001). Then the crucible was placed inside a muffled furnace so that it would

receive the required heat treatment. After activation with zinc chloride, the samples were washed with 1M hydrochloric acid solutions firstly and then with distilled water, until the pH value reached 7.0. After washing, the samples were dried in an oven at 105 °C for 24 h. Then the dried samples were preserved in desiccators to avoid further moisture absorption. The adsorbent showed a fluffy, highly porous, and rough microstructure, containing some voids and cracks which was suitable for the adsorption of Cu^{+2} ions. The concentration of Cu^{+2} ions in aqueous solution was analyzed, using Atomic Absorption Spectrometer (AAS). Mechanical shaker with adjustable speed time was used for agitation, while all pH rates were measured via a pH-meter.

One gram of activated carbon powder, prepared from cane papyrus, was used for the adsorption of Cu^{+2} ions onto the surface of activated carbon, again prepared from Cane Papyrus via a mechanical shaker with the speed of 200 rpm at 25C° . The effect of adsorbent dosage was investigated by altering the initial mass of the adsorbent between 5 and 100 gm, with the optimum dosage used for subsequent processes. Similarly, depending on the pH, initial Cu^{2+} removal was initiated by contacting 0.0 to 5.0 g of the adsorbent with 100 ml Cu^{2+} solution for 5–120 min in a closed cylindrical plastic vessel, 250 ml in volume.

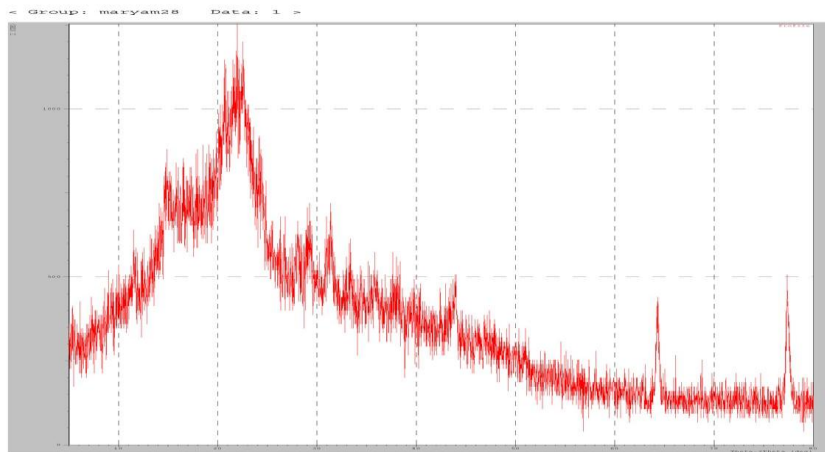
Copper(II) Sulfate Pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) was used as the source of Cu^{2+} ion in a simulated effluent solution, made from water with a TDS (total dissolved solid) of 200 mg/L and a pH value of 7. Hydrochloric acid and sodium hydroxide solutions, both with a concentration of 1M, were used to adjust the pH value. In the prepared solution samples, the contaminant concentrations were 2.0, 3.0, and 4.5 mg/L. After equilibration for 60 min, the adsorbent was recovered. Residual Cu^{+2} ions on the surface of the used adsorbent was removed by getting washed three times with ultra-pure water. De-ionized water, 1M NaOH, and 1M HCl were tested as potential desorbing agents, wherein 40 ml of the agents was introduced into a 100 ml Teflon container, containing the recovered adsorbent, then to get equilibrated for 60 min at a speed of 200 rpm and $T = 25\text{C}^\circ$. Following the equilibration, the aqueous solutions were centrifuged and the supernatant analyzed to determine the concentration of Cu^{+2} ions after desorption.

RESULTS AND DISCUSSION

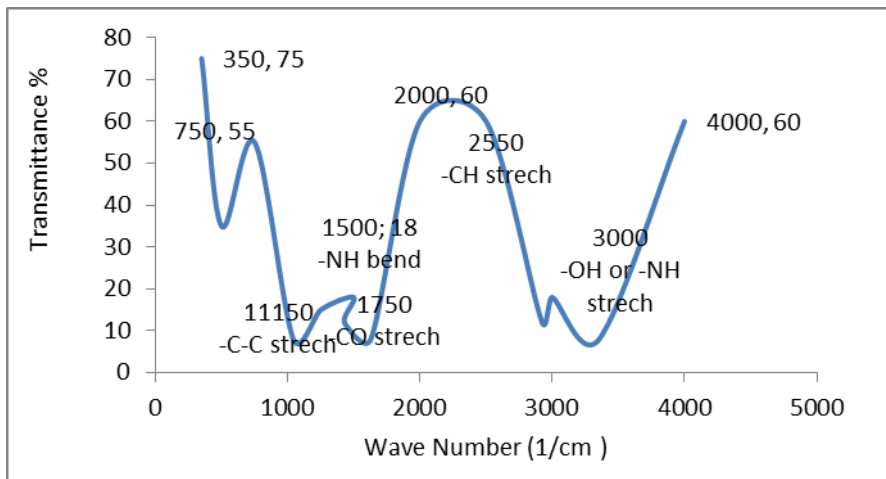
Results from the Fourier transform infra-red showed a broad peak at 3000 $1/\text{cm}$ with a high transmittance frequency, which can be attributed to either $-\text{OH}$ or $-\text{NH}$ groups. As shown in Figure 2.B, the band observed at

2550 $1/\text{cm}$ is possibly due to C–H stretching vibrations of saturated aliphatic compounds, as reported by Smith, whereas the one at 1750 $1/\text{cm}$ can be attributed to $-\text{NH}$ bending vibration of primary amines. A small peak was observed at 1350 $1/\text{cm}$, corresponding to $\nu(\text{C}-\text{C})$ stretching vibrations of aromatic rings. The peaks, observed at 1200 $1/\text{cm}$ and 1150 $1/\text{cm}$, corresponded to the C–O stretch of alcohols, carboxylic acids, esters, or ethers. The absorption band at 500 $1/\text{cm}$ can be due to the presence of an alkyl halide. Also it was confirmed that mucilage extracted from *Diceriocaryum* species contained carboxyl functional group. The presence of acidic functional groups was responsible for its adsorptive trait. Furthermore, it was clearly stated from previous studies of natural plant materials that the biochemical characteristics of acidic functional groups were responsible for their metal ion uptake (Smith, 2011).

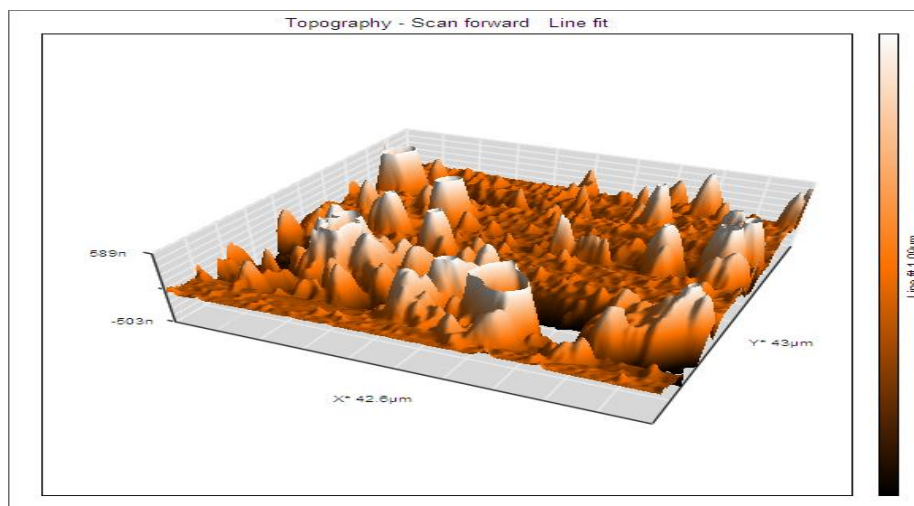
The present study used SEM images of cane papyrus char, treated with sodium hydroxide and activated with zinc chloride. SEM image of activated carbon prepared from Cane Papyrus was taken from International Centre for Diffraction Data equipment at Ibn-Alhathaim Lab, Baghdad University. SEM images of cane papyrus ash indicated a porous structure, which means that following combustion, organic compounds like carbon were driven off and silica remained as its structure in the cane papyrus. In reverse, if the silica was driven off from the cane papyrus char through the treatment of sodium hydroxide, then a porous carbon structure was obtained. For further development of porous structure, the sodium-hydroxide-treated cane papyrus got activated with zinc. The SEM image of activated carbon, treated with zinc chloride, shows the well-developed micro pore structure (Figure 2.C). The chemical composition of the adsorbent was analyzed via X-ray Fluorescence spectrometer. Table 1 gives the chemical composition of the adsorbent.



(A)



(B)



(C)

Fig. 2. SEM images of activated carbon, prepared from Cane Papyrus

Table 1. Chemical Composition of activated carbon, prepared from Cane Papyrus.

Compound	Wt %	Compound	Wt %
Na ₂ O	1.17	V ₂ O ₅	11.7
MgO	1.2	CaO	2.7
Al ₂ O ₃	25.9	SiO ₂	1.1
TiO ₂	1.33	P ₂ O ₅	17.6
MnO	0.778	Fe ₂ O ₃	2.0
SO ₃	1.2	SrO	1.24
V ₂ O ₄	2.3	BaO	1.5

Table 2. Characteristics of activated carbon, prepared from Cane Papyrus.

Physical Parameters	Result
BET surface area (m ² /g)	3.5
Micropore surface area (m ² /g)	1.75
Total pore volume (cm ³ /g)	1.5
Micropore volume (cm ³ /g)	1.02
Average pore diameter(Ao or 10 ⁻⁸ cm)	191

Surface area of the adsorbent was 3.5 m²/g (Table 2). The average pore diameter of activated carbon, prepared from Cane Papyrus, ranged between 10 and 1000 × 10⁻⁸ cm, with the adsorbent classified as a meso-porous material. Similarly, reported BET surface areas of 1.02 cm²/g and 3.75 m²/g for activated carbon from macadamia nuts were used for phenol removal and maize tassels for heavy metal removal from polluted waters, respectively, although adsorbents with higher surface areas have been widely reported in literature (Alatabe & Alaa, 2017).

The percentage of removing Cu⁺² ions from aqueous solution was estimated by means of Equation (1):

$$\text{Adsorption}(\%) = \frac{[C_i - C_f]}{C_i} \times 100 \quad (1)$$

where C_i and C_f are the initial and final metal ion concentrations, respectively.

$$q_e = \frac{(C_o - C_e)V}{w} \quad (2)$$

where q_e is the amount of metal adsorbed in mg/g, with C_i and C_e representing initial

and equilibrium concentrations of metal ions in aqueous phase. V is the volume of the solution in liters (L) and W, the weight of the adsorbent used in grams.

Figure 3 demonstrates the effect of pH on the variation of adsorption on the time of contact at the experimental work conditions: 30g adsorbent dosage, volume = 1L, and Cu²⁺ concentration = 5 mg/L. The initial pH of the solution was 8. Two other pH values of 6 and 2 were also investigated, with the best result achieved for the solution with pH value of 6. More alkaline solutions with pH values higher than 8 were not investigated, because metallic hydroxide (e.g. Cu(OH)₂) could be formed at high pH values in the alkaline range. Cu²⁺ ions was precipitated as Cu(OH)₂, quite difficult to be segregated from adsorbed and bio-adsorbed Cu²⁺. In essence, Cu²⁺ ions can be present as Cu⁺ as well, but Cu⁺ is not stable under atmospheric conditions. Since the aim of the present work was to investigate removal of Cu²⁺ ions from the effluent solutions, by means of activated carbon, prepared from Cane Papyrus, pH values were kept beneath 8.

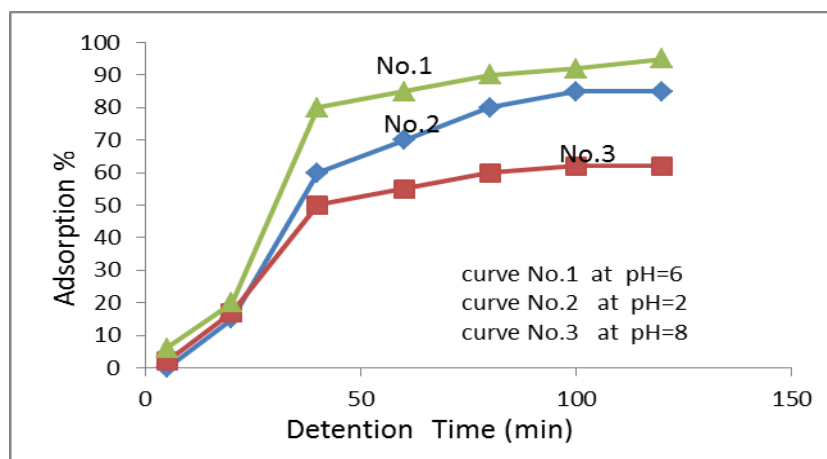


Fig. 3. Impact of pH values on Cu^{2+} ions adsorption (%), using activated carbon, prepared from Cane Papyrus

All the curves correspond to 120 minutes, with Curve No.1, Curve No.2, and Curve No.3, representing 98%, 80%, and 60% of Cu^{2+} ion removal, respectively. The lines are not fitting functions; they simply connect points to facilitate visualization. Increase in Cu^{2+} ions removal along with the increase in pH values can be explained on the basis of a decrease in competition between proton and metal cat-ions for reactions with the same functional groups. Another parameter is the decrease in positive charge of the adsorbent, which results in a lower electrostatic repulsion between the metal cat-ions and the surface. Carboxyl and sulfate groups have been identified as the main sites for attachment of metal ions with the main chemicals in seaweed and, as these groups can have acidic property, their presence is pH-dependent. These groups generate a negatively-charged surface within pH range of 3.5-5.0. Moreover, electrostatic interactions among cationic species and this surface were responsible for metal uptake. As the pH rose, the ligands such as carboxylate groups in *Sargassum* sp. would be exposed, increasing the negative charge density on biomass surface, enhancing the attraction of metallic ions with positive charge and allowing the bio sorption onto the cell surface. By increasing pH, the rate of adsorption also rose, with the optimum pH of

6 for copper bio sorption. Copper ion forms an insoluble hydroxide, precipitated at pH values above 8, consequently leading to no adsorption. Obviously metal adsorption depends on the nature of the adsorbent surface. At low pH, the H^+ ions compete with metal ions for the exchange sites in the system, thereby partially releasing metal ions.

Figure 4 shows, the increase of adsorption rate through raising the concentration of Cu^{2+} ions. A higher aqueous concentration of Cu^{2+} ions means more opportunities contact with a constant amount of the adsorbent.

The detention time for all curves is 120 minutes, while Curve No.1 represents 3 mg/L of initial concentration and 98% Cu^{2+} ion removal; Curve No.2, 2 mg/L of initial concentration and 80% Cu^{2+} ion removal; and Curve No.3, 1 mg/L of initial concentration and 60% Cu^{2+} ions removal. The lines are not fitting functions; they simply connect points to facilitate visualization. It is expected that when the initial ion concentration is increased, the rate of adsorption would increase, too. Referring to the limitation of the adsorption sites, increasing the initial Cu^{2+} concentration would reduce the ratio of Cu^{2+} which might be absorbed relative to the total amount of copper ions in the solution.

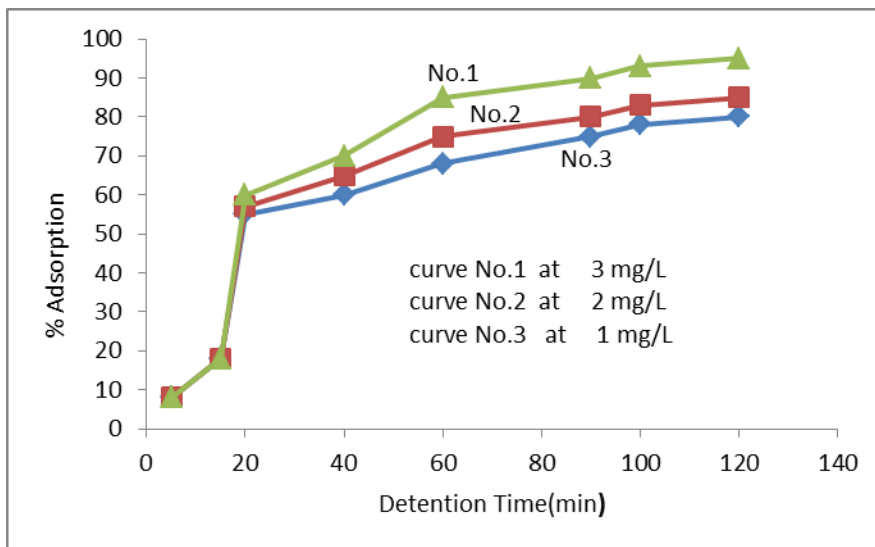


Fig. 4. Effect of initial concentration of Cu²⁺ ions on the efficiency adsorption onto activated carbon, prepared from Cane Papyrus

Figure 5 demonstrates changes of aqueous Cu²⁺ ion concentrations as a function of time for an adsorbent mass loading of 30 g/L. It can be seen that Cu²⁺ ion removal increased very sharply at the beginning, reaching 60% after some 30 minutes. After 80 minutes, a plateau was reached at about 60% Cu²⁺ ion removal and maintained until the end of the experiment (120 minutes) at about 98%. Data from Figure 6 suggest that 2 hours (120 minutes) are a suitable duration to achieve a pseudo-equilibrium under the experimental

conditions of this work. Figure 5 summarizes the effect of adsorbent mass loading, varying from 10 g/L to 30 gm/L for Cu²⁺ ion removal within 2 hours. The efficiency of Cu²⁺ ion removal was 20%, 60%, and 98% for 10, 20, and 30 gm/L of activated carbon prepared from Cane Papyrus, with a volume of 1L and Cu²⁺ concentration of 5mg/L. This plateau at the end of curves was probably from saturation of the surface of adsorbent with metal ions, followed by adsorption and desorption processes that occur afterwards.

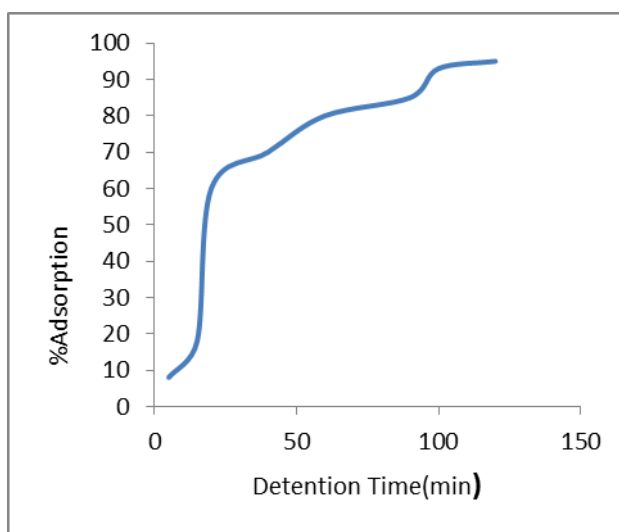


Fig. 5. Effect of activated carbon prepared from Cane Papyrus Dosage on the adsorption efficiency of Cu²⁺ ions

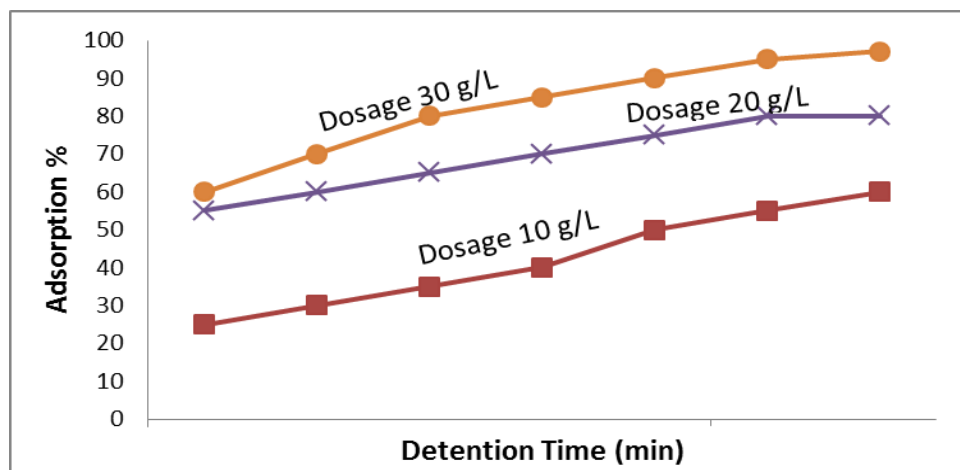


Fig. 6. Influence of various dosage of activated carbon, prepared from Cane Papyrus, on Cu⁺² ion adsorption efficiency

Experimental data for the adsorbed metal against initial concentration were fitted into the langmuir and Freundlich adsorption isotherms. The langmuir model (Langmuir, 1916) assumes that the adsorption of an ideal gas on an ideal surface occurs only at fixed number of sites, with each site capable of only holding one adsorbent molecule (monolayer). It also assumes that all available sites are equivalent and there is no interaction between adsorbed molecules on adjacent sites. The linearized equation for langmuir model (Langmuir, 1918; Xiao & Thomas, 2004) is represented by Equation (3).

$$\frac{l}{q_e} = \frac{l}{q_{max}} + \left\{ \frac{l}{bq_{max}} \right\} \frac{l}{C_e} \quad (3)$$

where C_e is the equilibrium concentration of the metal ion (mg/L); q_e , the quantity of Cu⁺² ion adsorbed at equilibrium (mg/g); q_{max} , the maximum amount adsorbed (mg/g); and b , the adsorption constant (L/mg). The plot of l/q_e against l/C_e gave a

straight line with a regression coefficient of 0.8999 (Figure 7), indicating that the adsorption conformed to langmuir model. The maximum concentration of adsorbed Cu⁺² ions as well as the adsorption capacity was calculated from the slope and intercept of the plot, which can be seen in Table 3. The conformity of the adsorption process to langmuir model was determined, using Equation (4):

$$R_l = \frac{l}{(l + bC_0)} \quad (4)$$

where R_l is the separation factor; C_0 , the initial metal concentration (mg/L); and b , the langmuir constant (l/mg). $R_l > 1$, $R_l = 1$, $0 < R_l < 1$, and $R_l = 0$ indicate unfavorable, linear, favorable, and irreversible monolayer adsorption process, respectively. Results from this study had an R_l value between zero and one, indicating a favorable adsorption process. This implies that chemisorptions process duly explain the adsorption of Cu⁺² ions onto activated carbon, prepared from Cane Papyrus.

Table 3. Freundlich and Langmuir constants for Cu⁺² ion adsorption onto activated carbon, prepared from Cane Papyrus

langmuir model				Freundlich model		
q_{max} (mg/g)	b	R_l (L/mg)	R^2	K_F	n	R^2
39.5	0.0315	0.0-1.0 (0.5)	0.8999	0.09	0.0927	0.9823

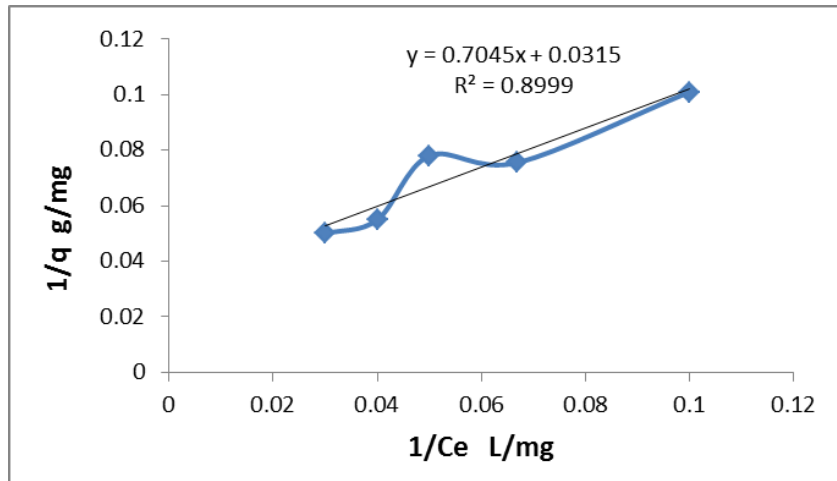


Fig. 7. Langmuir plot for Cu²⁺ ion adsorption onto activated carbon, prepared from Cane Papyrus

The Freundlich isotherm mode (Freundlich, 1906) describes a multi-site adsorption for heterogeneous surfaces and can be represented by Equation (5);

$$q_e = K_f C_e^{1/n} \quad (5)$$

where K_f is the adsorption capacity (L/mg) and $1/n$, the intensity of the adsorption, showing the heterogeneity of the adsorbent site as well as the distribution energy. Equation (6) was obtained by taking the logarithm of Equation (5):

$$\log q_e = \log K_f + \log C_e \quad (6)$$

A plot of $\log q_e$ against $\log C_e$ gave a linear graph with a regression coefficient

of 0.9823 (Figure 8), indicating that the adsorption also fits into Freundlich model. From the linearized coefficients, obtained from both models, the langmuir model described the adsorption process better than the Freundlich one. This suggests a chemisorptions rather than a physisorption process. Table 3 shows the constants, obtained for Freundlich and langmuir plot. A maximum adsorption capacity of 39.5 mg/g was obtained in this study for the adsorption of Cu²⁺ ions. The use of activated carbon, prepared from Cane Papyrus, is therefore a potential candidate for the removal of Cu²⁺ ions in water and wastewater.

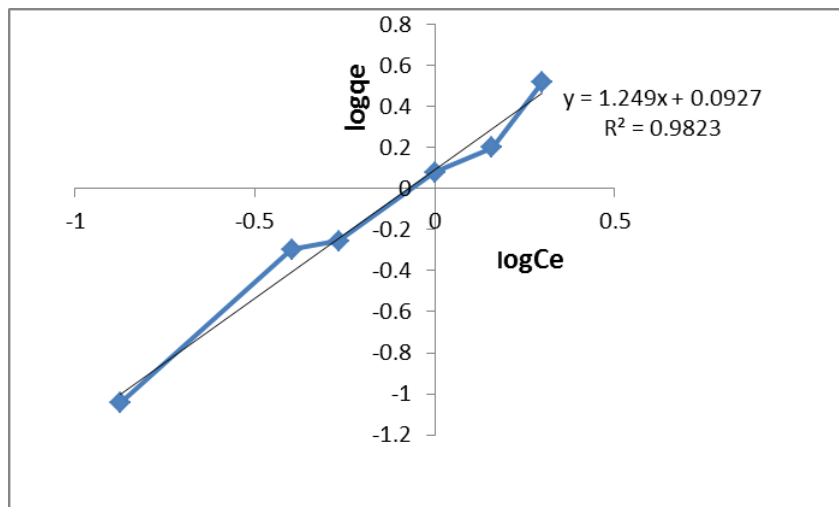


Fig. 8. Freundlich plot for Cu²⁺ ions adsorption onto activated carbon, prepared from Cane Papyrus

The mechanism adsorption reactions are usually carried out, using adsorption reaction and adsorption diffusion models. Both models are used to understand the kinetics of the reaction. The linearized equations for pseudo first- and pseudo second-order kinetics are presented in Equations (7) and (8), respectively.

$$\log(q_e - qt) = \log q_e - \left\{ \frac{Kt}{2.303} \right\} \quad (7)$$

$$\frac{t}{qt} = \left\{ \frac{1}{k_2 q_e^2} \right\} + \frac{1}{q_e} \quad (8)$$

where q_e and q_t stand for the amounts of Cu^{+2} ions adsorbed at equilibrium and at the given time t , respectively, while k_1 and

k_2 are the rate constants of pseudo first- and pseudo second-order models. The pseudo first-order kinetic model (Ho & Mckay, 1999) was used to treat the experimental data, obtained by plotting $\log(q_e - q_t)$ against equilibration time (Figure 10). A linearity coefficient of 0.8933 was obtained. Similarly, a linear graph ($R_2 = 0.983$) was obtained by plotting t/q_t values against time t (Figure 9). The pseudo second-order best described the kinetics of the adsorption process, which agreed with other results, reported in the literature. Results, obtained from the kinetic plot, favors chemisorptions mechanistic pathway rather than physisorption.

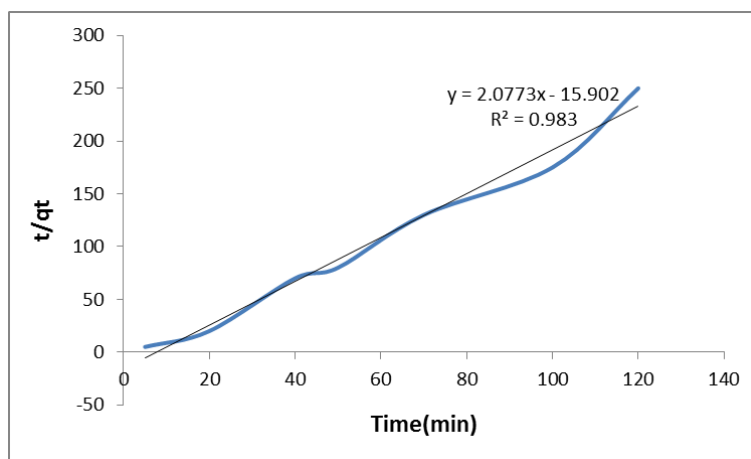


Fig. 9. Pseudo second-order kinetics for Cu^{+2} ion adsorption onto activated carbon, prepared from Cane Papyrus

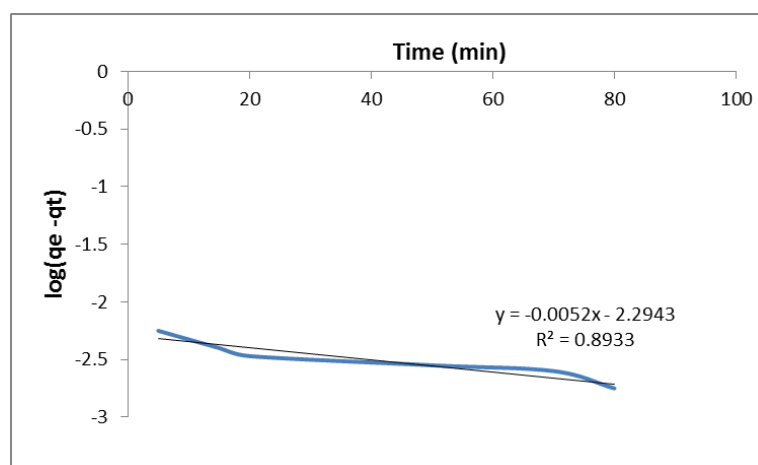


Fig. 10. Pseudo first-order kinetics for Cu^{+2} ion adsorption onto activated carbon, prepared from Cane Papyrus

Mechanism-Based Model Weber-Morris in Equation 9 was used to ascertain whether intra-particle diffusion or film diffusion (external diffusion) is the rate-controlling step.

$$qt = K_d(t)^{1/2} + I \quad (9)$$

where k_d is the intra-particle diffusion rate constant ($\text{mg/g min}^{-0.5}$) and I (mg/g), a constant describing the thickness of the boundary layer. A linear plot of qt versus $t^{1/2}$ passing through the origin suggests

intra-particle diffusion as the sole rate-determining step; however, if a linear plot was obtained, which did not pass through the origin, it meant the adsorption process was controlled by more than one mechanism. In this study, a linear plot was obtained that did not pass through the origin (Figure 11), suggesting that the mechanism of the reaction is multi-linear and the rate-limiting reaction was controlled both through film diffusion and intra-particle diffusion.

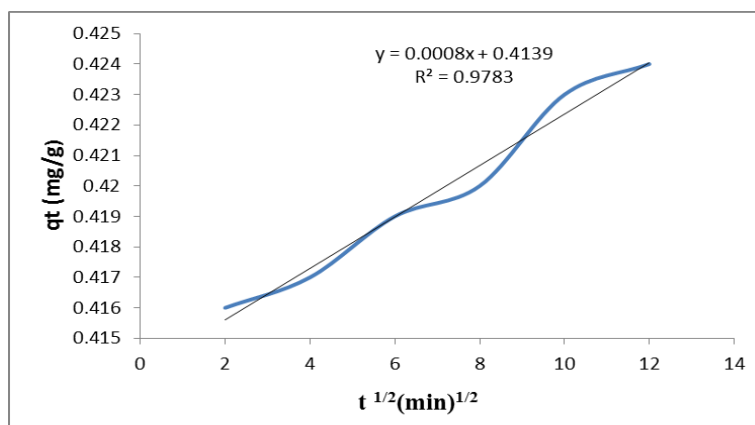


Fig. 11. Intra-particle diffusion model plot for Cu^{+2} ion adsorption onto activated carbon, prepared from Cane Papyrus

This study was carried out to assess the most suitable desorbing agent for eluting adsorbed Cu^{+2} ions from the surface of activated carbon, prepared from Cane Papyrus. The effects of de-ionized water, 0.5M NaOH, and 0.5M HCl solutions were tested for their ability to remove the adsorbed Cu^{+2} ions from the surface of the adsorbent. HCl was a better desorbing agent, capable of recovering 60% of Cu^{+2} ions, adsorbed to the surface of the adsorbent. NaOH and de-ionized water showed desorption efficiencies of 30% and 2%, respectively. Desorption is beneficial for the separation and enrichment of Cu^{+2} ions as well as the regeneration of the adsorbent.

CONCLUSION

The adsorption ability of powdered activated carbon, prepared from Cane Papyrus, was investigated and found

effective for the removal of Cu^{+2} ions from wastewater. Acidic functional groups, present on the surface, and sustainability of the adsorbent are believed to be responsible for the removal of Cu^{+2} ions from aqueous media. The Freundlich isotherm model gave a better description of the adsorption process than the Langmuir isotherm model. Pseudo-second order kinetics best described the kinetics of the reaction, while 0.5 M HCl was a better desorbing agent than 0.5 M NaOH as well as de-ionized water.

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