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ADSORPTION OF COPPER (II) IONS FROM AQUEOUS SOLUTION BY ACTIVATED CORCHORUS OLITORIUS - L LEAVES: EQUILIBRIUM ISOTHERMS AND KINETIC APPROACH

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ABSTRACT

Sorption techniques are widely used to remove heavy metal ions from large volumes of aqueous solutions. The series of batch laboratory experiment were carried out by using Activated Corchorus Olitorius Nano Carbon (ACONC) for the removal of copper (II) ions from aqueous solution by the adsorption process. The investigation was carried out by studying the influence of initial pH, contact time, adsorbent dosage and initial concentration of copper. All batch experiment was carried out of constant temperature using wrist – action shaker that operated at 150 rpm. The single component equilibrium data was analyzed by Langmuir and Freundlich isotherms. Maximum adsorption of the copper (II) ions, i.e. >90% has been achieved in aqueous solutions using 0.025g of ACONC at a pH of 6.5. The kinetic process of copper ACONC was described by applying pseudo second order rate equation, Elovich model and intra- particles diffusion. The ACONC investigated in this study carries high potential for the removal of copper ions from aqueous solution. The various thermodynamic parameters like ΔG^0 , ΔH^0 , and ΔS^0 were analyzed to observe the nature of adsorption.

Key words: Copper (II), Activated Corchorus Olitorius Nano Carbon (ACONC) adsorbent, batch adsorption, adsorption isotherms, kinetics and Thermodynamics.

INTRODUCTION

Water pollution is due to the mixing of toxic metals and organic compounds excreted from industries in to the water bodies that cause serious environmental and public problems. Hence this has been becoming an alarming concern and priority of the most industrial sectors to avoid such problem. Heavy metal ions are often found in the environment as result of their wide industrial uses. They are common contaminants in waste water and many of them are known to be toxic or carcinogenic [1,2].

In addition, heavy metals are non-biodegradable and tend to accumulate in living organisms, causing various diseases and disorders. Therefore, their presence in the environment, in particular in water, should be controlled [3,4]. Strict legislation on the discharge of these toxic products makes it then necessary to develop various efficient technologies for the removal of pollution from waste water. Biological treatments [5], membrane process

[6], advanced oxidation process [7,8], chemical and electrochemical techniques [9-11] is the most widely used for removing metals and organic compounds from industrial effluents. Amongst all the treatments proposed, adsorption using sorbents is one of the most popular methods since proper design of the adsorption process will produce high-quality treated effluents. In fact, adsorption is now recognized as an effective, efficient and economic method for water decontamination application and for separation analytical purposes. The adsorbents may be of mineral, organic, biological origin, activated carbons, zeolites, clays, silica beads, low-cost adsorbents (industrial by-products, agricultural wastes and biomass) and polymeric materials are significant examples [12,13].

In order to assess the ability of activated Nano Carbon for metal ions removal, copper (II) has been selected for the present study.

MATERIALS AND METHODS

Adsorbent

The *Corchorus Olitorius* Leaves collected from nearby Thiruvapur district was carbonized with concentrated Sulphuric Acid and washed with water and activated around 900°C in a muffle furnace for 6 hrs then it was taken out and stored in a vacuum desiccators.



Figure 1. *Corchorus olitorius* L

Chemicals

All chemicals used of high purity commercially available Analar grade. 1000 mg/L of stock solution of copper ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) was prepared by dissolving accurately weighed 3.9294 gram of copper sulphate in 1000 ml distilled water. All experimental solutions were prepared by diluting the stock solution to the required concentration. The pH of each experimental solution was adjusted to the required initial pH value using dilute HCl (or) NaOH before mixing the adsorbent. The concentration of residual copper (II) ion was determined with atomic absorption spectrophotometer (Perkin Elemer 2380).

Batch experiments

The effect of various parameter on the removal of copper (II) onto ACONC was studied batch adsorption experiments were conducted at (30-60°C). For each experimental run, 50 ml of copper solution of known initial concentration and pH were taken in a 250 ml plugged conical flask. A 25 mg adsorbent dose is added to the solution and mixture was shaken at constant agitation speed (150 rpm) sample were withdrawn at appropriate time intervals (10-60 min) and the adsorbent was separated by filtration. The residual solutions were analyzed to determine the copper (II) concentration.

The effect of dosage of adsorbent on the removal of copper (II) was measured by contacting 50 ml of 50 mg/L of copper (II) solution with 25 mg of ACONC till equilibrium was attained.

Adsorption equilibrium isotherm is studied using 25 mg of ACONC dosage per 50 ml of copper (II) solution. The initial concentration were ranged from (25 to

125 mg/L) in all sets of experiments. The plugged conical flask was shaken at a speed of 150 rpm for 60 minutes. Then the solution was separated from the mixture and analyzed for copper (II) concentration. The adsorption capacity was calculated by using a mass equilibrium equation as follows:

$$q_e = (C_0 - C_e) V/M \dots\dots\dots (1)$$

Where, C_0 and C_e being the initial copper (II) ion concentration (mg/L) and equilibrium concentration, respectively V is the experimental volume of copper (II) ion solution expressed in liters [L] and M is the adsorbent mass expressed in grams [g]. The copper (II) ions percentage can be calculated as follows:

$$\%R = (C_0 - C_t) \times 100/C_0 \dots\dots\dots (2)$$

The effect of pH on the rate of adsorption was investigated using copper concentration of 25 mg/L constant ACONC dosage. The pH values were adjusted with dilute HCl and NaOH solution. The adsorbent – adsorbate mixture was shaken at room temperature using agitation speed (150 rpm) for 60 minutes. Then the concentration of copper in solution was determined.

Batch kinetic studies

The batch kinetic [14] experiments were basically identical to these of adsorption equilibrium method. The aqueous samples were taken at present time intervals and the concentration of copper (II) ions was similarly measured. The all kinetic experiments are carried out at 30, 40, 50 and 60°C at an initial concentration of 25, 50, 75, 100 and 125 mg/L. the amount of adsorption at time t , q_t (mg/g) was calculated by.

$$q_t = (C_0 - C_t) V/W \dots\dots\dots (3)$$

RESULTS AND DISCUSSION

Effect of initial concentration

The experimental results of adsorption of copper (II) ions on ACONC at various initial concentration (25, 50, 75, 100 and 125 mg/L) for copper (II) ions in terms of equilibrium data are given in table 1. It reveals that, the actual amount of copper (II) ions adsorbed per unit mass of Activated *Corchorus Olitorius* Nano Carbon with increase in copper (II) ions concentration shown in Fig.1. It means that the adsorption is highly dependent on initial concentration of copper (II) ion. It is because of at lower concentration, the ratio of initial number of copper (II) ions to the available surface area is less subsequently the fractional adsorption become independent of initial concentration. However at high concentration the available sites of adsorption becomes fewer and hence the amount of copper (II) ions adsorbed on the adsorbent surface is less.

Effect of contact time

The effect of contact time on the adsorption of copper ions on the adsorbent surface was shown in Fig.1 reveals that the curves are smooth and continuous leading

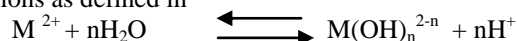
to saturation, suggesting the possible mono layer coverage of the copper (II) ions on Activated Corchorus Olororius Nano Carbon surface at about 50 minutes and once again there is not a big change of amount of copper (II) ion adsorbed with time, which gives an indication that of ion exchange [15].

Effect of adsorbent dosage

The adsorbent dosage is an important parameter, which influence the extent of copper (II) uptake from the solution. The effect of varying doses of 10 to 250 mg of ACONC was investigated using 50 mg/L of initial copper (II) ion concentration at initial pH 6.5 shows an increase in percentage removal of copper with increase in dose of adsorbent up to a certain limit shown in Fig.2. Increase in the adsorption with increasing dose of adsorbent is expected due to the increase in adsorbent surface area and availability of more adsorption site [16].

Effect of pH

The experiment were carried out of different pH shows that there was a change in the quantity of adsorbed copper (II) ions on the solid phase of ACONC over the entire pH range of 2 to 10 for copper (II) ion shown in Fig.3. The solution pH plays a major role in determining the amount of copper ions adsorption. The initial copper (II) ion concentrations were kept constant. Adsorption of copper (II) ions increased appreciably (1-2 times) with increase of pH from 2 to 10 and consistent with results obtained by others. The increase is partly attributed to the formation of different hydroxo species with rise in solution pH. Based on the hydrolysis constants of copper (II) ions as defined in



and taking only primary metal species expected to be formed in the working pH range into consideration, the species distribution diagrams for copper ion is constructed and given in Fig. 3. It is evident that Cu^{2+} and its monohydroxo species are the predominating species up to pH ~ 9, while dihydroxo species are also formed to a significant extent above pH ~ 7.0 for copper ion. Since, maximum adsorption copper ion was achieved at pH ~ 6.5, it may safely be stated that the removal of copper (II) ion was mostly due to adsorption and not precipitation. However, precipitation of small fractions of Cu^{2+} even at pH ~ 6.5 on the surface by nucleation cannot be neglected. At still higher pH (>7), however, part of Cu^{2+} may be precipitated as dihydroxo species, which also depend upon the initial copper (II) ion concentration. The other important factor, which might contribute to the higher adsorption of copper (II) ion with increased pH, is the pH_{zpc} of ACONC. At any pH below pH_{zpc} the surface of metal oxides/ oxyhydroxides is positively charged and at pH above pH_{zpc} the surface is negative. When the solution pH exceeded pH_{zpc} , the metal species are more easily attracted by the negatively charged surface of

adsorbent, favoring accumulation of metal species on the surface and thus promoting adsorption [17].

Adsorption isotherm

Freundlich isotherm

The linear form of Freundlich isotherm [18] is represented by the equation

$$\log q_e = \log K_f + (1/n) \log C_e \dots\dots\dots(4)$$

Where, q_e is the amount of copper (II) ions adsorbed per unit weight of the sorbent (mg/L), K_f is a measure of adsorption capacity and $1/n$ is the adsorption intensity. The value of K_f and n are calculated from the intercept and slope of the plot of $\log q_e$ Vs $\log C_e$ respectively. The constant K_f and n values are given in (table 2). In general K_f value increases the adsorption capacity for a given adsorbate increases. The magnitude of the exponent $1/n$ gives an indication of the favorability of adsorption. The value of $n > 1$ represents favorable adsorption condition (or) the value of $1/n$ are lying in the range of 1 to 10 confirms the favorable condition for adsorption. The adsorption co-efficient K_f of copper (II) ion on ACONC was found to be around 5.0 L/g. The K_f values indicates that the saturation time for adsorption of copper (II) ion is attained quickly slue to high affinity of ACONC towards adsorbate, while low K_f values indicates low adsorption rate of copper (II) ion. The values of $1/n$ were around 2.4 (mg/L) for copper (II) ions. The high values of $1/n$ signifies that the forces which are exerted on the surface of ACONC during copper (II) ion adsorption are strong rate from the values K_f and $1/n$ it is reveals that ACONC is more efficient for removal of copper ions.

Langmuir isotherm

The Langmuir isotherm model [19] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. The linear form of the Langmuir isotherm equation can be described by

$$C_e/q_e = (1/Q_m b) + (C_e/Q_m) \dots\dots\dots(5)$$

Where, C_e (mg/L) is the equilibrium concentration of the adsorbate, q_e (mg/g) is the amount of adsorbate per unit mass of adsorbent, Q_m and b are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the amount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption capacity of the adsorbent and b (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption). The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e). The Langmuir constant Q_m and b were determined from the slope and intercept of the plot and are presented in table 2. In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless constant separation factor R_L [20] by the equation

$$R_L = (1/(1+bC_o)) \dots\dots\dots(6)$$

Where, C_o (mg/L) is the highest initial concentration of adsorbent and b (L/mg) is Langmuir isotherm constant. The parameter R_L indicates the nature of shape of the isotherm accordingly.

$R_L > 1$ Unfavorable adsorption $0 < R_L < 1$ Favorable adsorption
 $R_L = 0$ Irreversible adsorption $R_L = 1$ Linear adsorption

The R_L values between 0 to 1 indicate favorable adsorption for all initial concentration (C_o) and temperatures studied. The calculated R_L values are given in table 3. The values of b were increased with increasing the dose of adsorbent for ACONC High 'b' values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 272 mg/L for ACONC.

Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0), and standard entropy change (ΔS^0) were calculated as follows. The free energy of adsorption process considering the adsorption equilibrium constant K_0 is given by the equation

$$\Delta G^0 = -RT \ln K_0 \dots\dots\dots (7)$$

Where, ΔG^0 is the free energy of adsorption (kJ/mol), T is the temperature in Kelvin and R is the universal gas constant (8.314 J mol/K). The adsorption distribution coefficient K_0 for the sorption reaction was determined from the slope of the plot of $\ln(q_e/C_e)$ against C_e at different temperature and extrapolating to zero C_e according to the method suggested by Khan and Singh [21]. The adsorption distribution coefficient may be expressed in terms of enthalpy change (ΔH^0) and entropy change (ΔS^0) as a function of temperature,

$$\ln K_0 = (\Delta H^0/RT) + (\Delta S^0/R) \dots\dots\dots(8)$$

Where, ΔH^0 is the standard heat change of sorption (kJ/mol) and ΔS^0 is standard entropy change (kJ/mol). The value of ΔH^0 and ΔS^0 can be obtained from the slope and intercept of plot of $\ln K_0$ against $1/T$. The value of thermodynamic parameter calculated from equation 7 and 8 are shown in table 4. The thermodynamic treatment of the sorption data indicates that ΔG^0 values were negative at all temperature. The results point out that physisorption is much more favorable for the adsorption of copper (II) ions. The positive values of ΔH^0 show the endothermic nature of adsorption and it governs the possibility of physical adsorption [22]. Because in the case of physical adsorption, while increasing the temperature of the system, the extent of copper (II) ion adsorption increases, this rules out the possibility of chemisorptions. The low ΔH^0 value depicts copper (II) ion is physisorbed onto adsorbent ACONC. The negative ΔG^0 values (table 4) were confirming the spontaneous nature of adsorption copper (II) ions onto ACONC. The lesser values of ΔG^0 suggest that adsorption is physical adsorption process.

The positive value of ΔH^0 further confirms the endothermic nature of adsorption process. The positive values of ΔS^0 in table 4, showed increased randomness of the solid solution interface during the adsorption of copper (II) ion onto Activated Corchorus Olitorius Nano Carbon.

Adsorption kinetics

The study of adsorption dynamics describes the solute up take rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of copper (II) ions adsorption on the ACONC were analyzed using pseudo-second-order, Elovich and intra-particle diffusion kinetic models. The conformity between experimental data and the model predicted values was expressed by the correlation Co-efficient (γ) and the values are close or equal to 1. A relatively high correlation coefficient (γ) value indicates that the pseudo second-order model successfully describes the kinetics of copper (II) ions adsorption.

The pseudo second- order equation

The pseudo second-order adsorption kinetic rate equation is expressed as

$$dq_t/dt = k_2(q_e - q_t)^2 \dots\dots\dots(9)$$

Where: k_2 is the rate constant of pseudo second- order adsorption ($\text{mg g}^{-1}\text{min}^{-1}$). For the boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$ the integrated form of Eq. (9) becomes:

$$1/(q_e - q_t) = 1/q_e + k_2 t \dots\dots\dots (10)$$

This is the integrated rate law for a pseudo second-order reaction. Equation (10) can be rearranged to obtain Eq.(11), which has a linear form:

$$t/q_t = (1/k_2 q_e^2) + ((1/q_e)t) \dots\dots\dots(11)$$

If the initial adsorption rate (h) ($\text{mg g}^{-1}\text{min}^{-1}$) is :

$$h = k_2 q_e^2 \dots\dots\dots (12)$$

Equation (9) and (10) becomes,

$$t / q_t = 1 / h + 1 / q_e t \dots\dots\dots (13)$$

The plot of (t/q_t) and t of Eq. (13) gives a linear relationship from which q_e and k_2 can be determined from the slope and intercept of the plot, respectively. The pseudo-second order rate constants k_2 , the calculated h values, and the correlation coefficients (γ) are summarized in Table 5. At all studied initial copper concentrations, the straight lines with extremely high correlation co-efficient (>0.99) were obtained. From table 5, the values of the rate constant k decrease with increasing initial copper concentration for ACONC. This shows that the sorption of copper (II) ions on ACONC follows pseudo second order kinetic model [23].

The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / dt = \alpha \exp(-\beta q_t) \dots\dots\dots(14)$$

Where, α is the initial adsorption rate ($\text{mg g}^{-1}\text{min}^{-1}$) and β is desorption constant (g/mg) during any one experiment.

To simplify the Elovich equation. Chien and Clayton [24] assumed $\alpha\beta t \gg t$ and by applying boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ Eq. (14) becomes:

$$q_t = 1/\beta \ln(\alpha\beta) + 1/\beta \ln t \dots\dots\dots (15)$$

If copper (II) ions adsorption fits with the Elovich model, a plot of q_t vs $\ln(t)$ should yield a linear relationship with a slope of $(1/\beta)$ and an intercept of $(1/\beta)\ln(\alpha\beta)$. The Elovich model parameters α , β , and correlation coefficient (γ) are summarized in table 5. The experimental data such as the initial adsorption rate (α) adsorption constant (β) and the correlation co-efficient (γ) calculated from this model indicates that the initial adsorption (α) increases with temperature similar to that of initial adsorption rate (h) in pseudo-second-order kinetics models. This may be due to increase the pore or active site on the ACONC adsorbent.

The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris [25] based on the following equation for the rate constant:

$$q_t = k_{id} t^{(1/2)} + C \dots\dots\dots (16)$$

Where, k_{id} is the intra-particle diffusion rate constant ($\text{mg g}^{-1} \text{min}^{-1/2}$) and C is the constant. The rate limiting step is intra-particle diffusion, when the graph was drawn between (q_t) (mg/g) versus square root of the contact time ($t^{1/2}$) yields a straight line passing through the origin. The

slope of gives the value of the intra-particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicate the fitness of this model. The value of 'C' gives an idea about the thickness of the boundary layer. The intercept value indicates that the line was not passing through origin, there are some other process affect the adsorption. But the correlation coefficient (γ) value is very high, so that the intra-particle diffusion takes place along with other process that may affect the adsorption. The values are given in table 5.

Evidences for adsorption

The FT-IR spectra of the ACONC before and after adsorption of copper ion are shown in Fig. 4a and Fig. 4b. It could be seen that the slight reduction of stretching vibration adsorption bands. This clearly indicates the adsorption of copper ion on the adsorbent by physical forces not by chemical combination. The XRD diagrams of ACONC and copper ion adsorbed ACONC are shown in Fig. 5a and Fig 5b. The intense main peak shows the presence of highly organized adsorbed ACONC, after the adsorption of copper (II) ion, the intensity of the highly organized peaks is slightly diminished. This was attributed to the adsorption of copper ion on the upper layer of the crystalline structure of the ACONC surface by means of physisorption.

Table 1. Equilibrium parameters for the adsorption of copper ion onto ACONC

Cu ₀	Ce (Mg / L)				Qe (Mg / g)				Removed (%)			
	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C
25	2.243	2.006	1.904	1.867	45.43	45.98	46.19	46.27	90.86	91.97	92.38	92.54
50	7.627	6.822	5.036	5.022	84.74	86.34	89.92	89.95	84.74	86.34	89.92	89.95
75	15.03	14.03	12.22	10.73	119.9	121.9	125.5	128.5	79.95	81.28	83.69	85.68
100	29.03	27.98	12.22	23.98	141.9	144.0	175.5	152.0	70.96	72.01	87.77	76.01
125	46.83	43.72	25.82	38.90	156.3	162.5	198.3	172.1	62.52	65.02	79.33	68.87

Table 2. Langmuir and Freundlich isotherm parameter for the adsorption of copper ion onto ACONC

Temp. (°C)	Langmuir parameter		Freundlich parameter	
	Q _m	B	K _f	n
30°	181.22	0.12	4.66	2.39
40°	186.67	0.13	4.79	2.42
50°	271.82	0.09	4.62	1.75
60°	196.94	0.16	5.00	2.36

Table 3. Dimensionless separation factor (r₁) for the adsorption of copper ion onto ACONC

(C _i)	Temperature °C			
	30°C	40°C	50°C	60°C
25	0.23	0.22	0.28	0.19
50	0.13	0.12	0.16	0.10
75	0.09	0.08	0.11	0.07
100	0.07	0.06	0.09	0.05
125	0.05	0.05	0.07	0.04

Table 4. Thermodynamic parameter for the adsorption of copper ion onto ACONC

C ₀	ΔG°				ΔH°	ΔS°
	30° C	40° C	50° C	60° C		
25	-5786.1	-6346.5	-6702.7	-6972.1	6.11	39.51
50	-4319.1	-4798.5	-5878.6	-6068.4	14.96	63.61
75	-3485.4	-3821.6	-4392.9	-4953.7	11.56	49.47
100	-2250.9	-2459.8	-5293.1	-3194.0	15.58	59.39
125	-1289.8	-1613.2	-3613.3	-2199.3	13.52	49.38

Table 5. The kinetic parameters for the adsorption of copper ion onto ACONC

Cu ₀	Temp °C	Pseudo Second Order				Elovich Model			Intraparticle Diffusion		
		q _e	k ₂	γ	h	α	β	γ	K _{id}	γ	C
25	30	49.74	22×10 ⁻³	0.9940	7.132	131.18	0.16	0.9921	1.67	0.9924	0.15
	40	50.51	21×10 ⁻³	0.9953	6.905	106.12	0.15	0.9914	1.66	0.9942	0.15
	50	50.42	20×10 ⁻³	0.9971	7.676	108.16	0.15	0.9931	1.67	0.9914	0.16
	60	51.07	21×10 ⁻³	0.9991	7.593	83.62	0.14	0.9954	1.66	0.9923	0.17
50	30	93.40	26×10 ⁻³	0.9984	12.74	148.53	0.07	0.9912	1.61	0.9918	0.16
	40	95.02	25×10 ⁻³	0.9975	13.91	186.05	0.07	0.9961	1.64	0.9924	0.16
	50	98.49	23×10 ⁻³	0.9983	13.91	164.46	0.07	0.9943	1.64	0.9917	0.16
	60	96.68	21×10 ⁻³	0.9997	16.32	386.72	0.08	0.9917	1.68	0.9934	0.14
75	30	133.3	29×10 ⁻³	0.9965	15.91	116.23	0.05	0.9981	1.55	0.9917	0.19
	40	135.7	28×10 ⁻³	0.9974	17.90	151.67	0.05	0.9917	1.58	0.9920	0.18
	50	137.8	26×10 ⁻³	0.9963	19.82	223.49	0.05	0.9937	1.61	0.9916	0.16
	60	140.4	25×10 ⁻³	0.9946	16.55	313.88	0.05	0.9928	1.63	0.9914	0.15
100	30	162.7	33×10 ⁻³	0.9958	15.65	69.51	0.03	0.9914	1.43	0.9911	0.23
	40	161.4	29×10 ⁻³	0.9919	19.07	136.86	0.04	0.9925	1.50	0.9921	0.19
	50	166.3	14×10 ⁻³	0.9946	19.34	134.12	0.03	0.9916	1.51	0.9934	0.19
	60	169.4	29×10 ⁻³	0.9986	22.27	186.01	0.04	0.9935	1.55	0.9921	0.18
125	30	180.0	31×10 ⁻³	0.9975	17.11	73.20	0.03	0.9974	1.37	0.9932	0.23
	40	184.8	30×10 ⁻³	0.9977	18.84	100.31	0.03	0.9941	1.42	0.9922	0.21
	50	195.6	21×10 ⁻³	0.9980	17.76	70.63	0.02	0.9913	1.39	0.9981	0.24
	60	195.9	31×10 ⁻³	0.9974	20.71	102.35	0.03	0.9924	1.44	0.9954	0.21

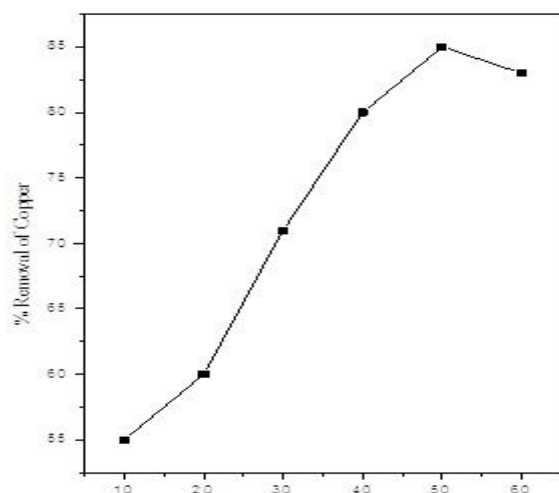
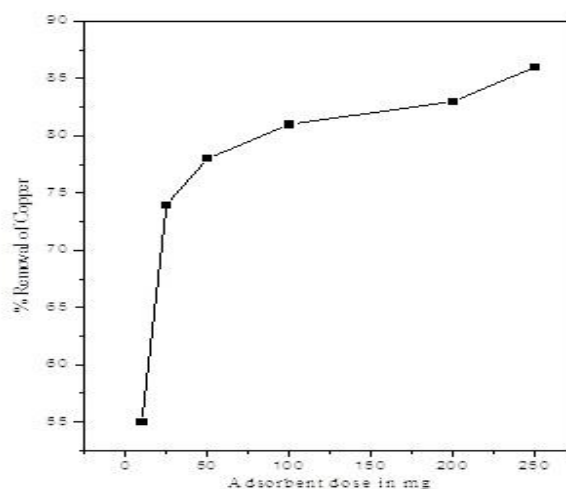
Figure 1. Effect of Contact Time on the Removal of Copper ion [Cu(II)] = 50 mg/L; Temperature 30°C; Adsorbent dose = 25mg/50 ml**Figure 2. Effect of Adsorbent dose on the removal of Copper ion [Cu(II)] = 50 mg/L; Contact Time 50 min; Temperature 30°C**

Figure 3. Effect of Initial pH on the removal of copper ion [Cu(II)] [MG] = 50 mg/L; Temperature 30°C; Adsorbent dose = 25mg/50 ml

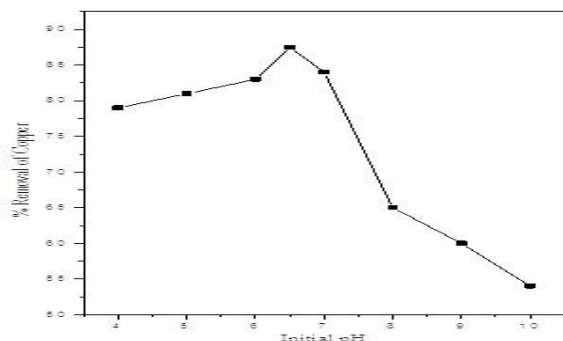


Figure 4a. FT-IR Spectrum of ACONC before adsorption

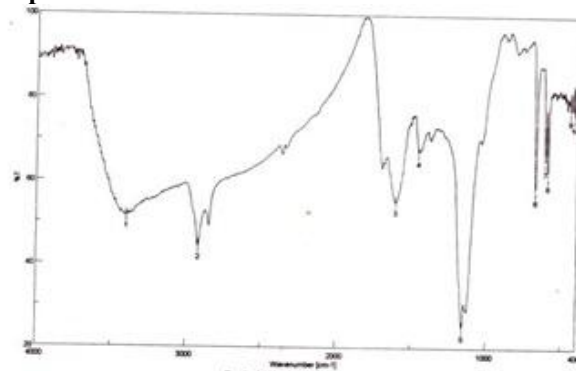


Figure 4b. FT-IR Spectrum of ACONC after the adsorption of copper ion

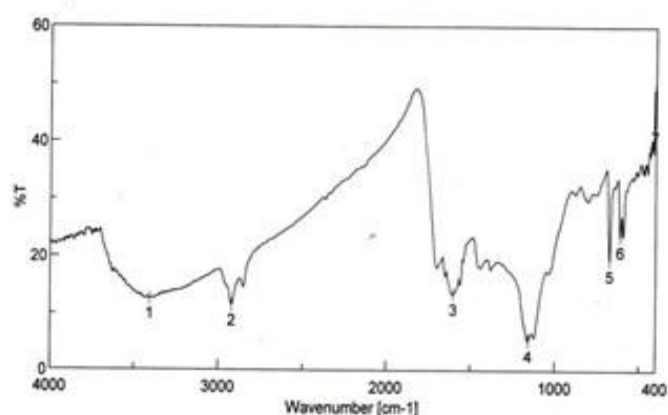


Figure 5a. XRD pattern of ACONC before adsorption

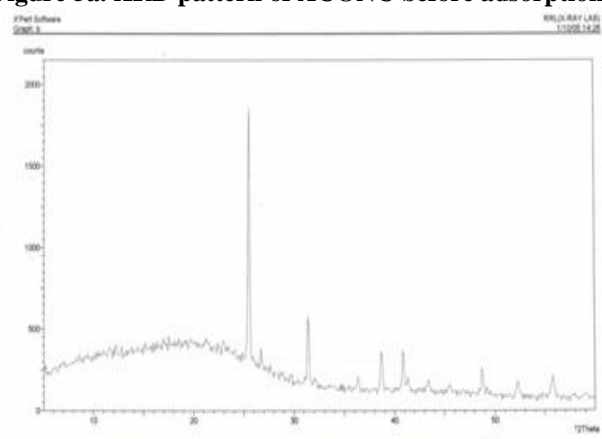
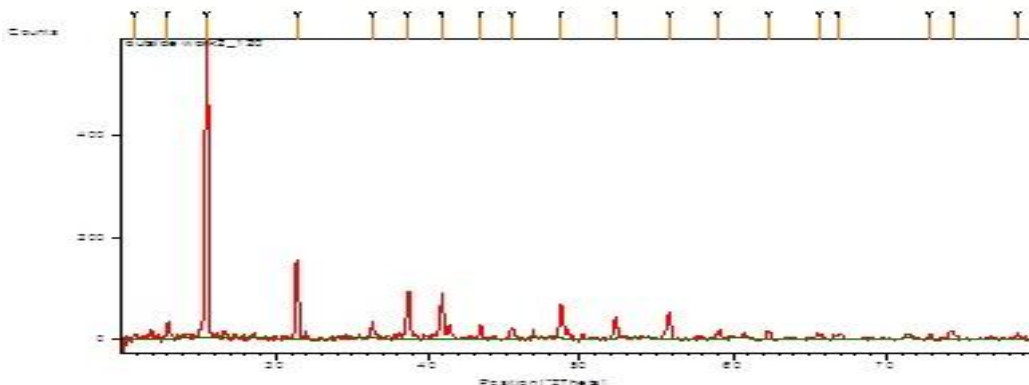


Figure 5b. XRD pattern of ACONC after the adsorption of copper ion



CONCLUSION

The adsorption characteristics of copper (II) ions onto Activated Corchorus Olitorius Nano Carbon are strongly affected by the initial copper (II) ion concentration, initial pH and the adsorbent dose. The pH 6.5 was favorable for the optimum adsorption of copper (II) by ACONC. The R_L values and other adsorption parameters indicate both Langmuir and Freundlich isotherms favorable for ACONC adsorption. The pseudo second order, Elovich and intra-particle kinetic model

were found to be applicable for the adsorption of copper (II) ions onto ACONC reaction model. The thermodynamics parameters ΔG^0 , ΔH^0 and ΔS^0 values indicate the adsorption is endothermic and physical adsorption.

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