

# Adsorption of Cu (II) Ions from Aqueous Solution by Activated Ipomoea Carnea: Equilibrium Isotherms and Kinetic Approach

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**Abstract:** The series of batch laboratory experiment were carried out by using Acid Activated Ipomoea Carnea (AAIC) 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 200 rpm. The single component equilibrium data was analyzed by Langmuir and Freundlich isotherms. Maximum adsorption of the copper ions, i.e. >90% has been achieved in aqueous solutions using 0.025g of AAIC at a pH of 6.6. The kinetic process of copper AAIC was described by applying pseudo second order rate equation, Elovich model and intra- particles diffusion. The activated AAIC investigated in this study carries high potential for the removal of copper ions from aqueous solution. The various thermodynamic parameters like  $\Delta G^0$ ,  $\Delta H^0$ , and  $\Delta S^0$  and were analyzed to observe the nature of adsorption.

**Key words:** AAIC adsorbent, Adsorption isotherms, Batch adsorption, Cu (II), Kinetics and Thermodynamics.

## I. 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 not 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], [6], membrane process [7], advanced oxidation process [8], [9], chemical and electrochemical techniques [10], [11], and adsorption procedures [12], [13], are 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 [14], [15].

## II. MATERIALS AND METHODS

### A. Adsorbent

The Ipomoea Carnea leaves obtained from Agricultural fields with waste water was Carbonized with concentrated Sulphuric Acid and washed with water and activated around 400°C in a muffle furnace for 5 hrs the it was taken out, ground well to fine powder and stored in a vacuum desiccators.



Fig 1: Ipomoea Carnea

### B. 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 1 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) was determined with atomic absorption spectrophotometer (Perkin Elemer 2380).

### C. Batch experiments

The effect of various parameter on the removal of copper (II) onto AAIC 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 (200 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 AAIC till equilibrium was attained. Adsorption equilibrium isotherm is studied using 25 mg of AAIC 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 200 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 concentration (mg/L) and equilibrium concentration, respectively V is the experimental volume of copper (II) 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 75 mg/L constant AAIC dosage. The pH values were adjusted with dilute HCl and NaOH solution. The adsorbent – adsorbate mixture was shaken at room temperature using agitation speed (200 rpm) for 60 minutes. Then the concentration of copper in solution was determined.

**D. Batch kinetic studies**

The batch kinetic [16] 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.

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

**III. RESULTS AND DISCUSSION**

**A. Effect of initial concentration**

The experimental results of adsorption of copper (II) ions on AAIC at various initial concentration (25, 50, 75, 100 and 125 mg/L) for copper ions in terms of equilibrium data are given in (table I). It reveals that, the actual amount of copper ions adsorbed per unit mass of Acid Activated Ipomoea Carnea increased with increase

in metal ions concentration shown in Fig.1. It means that the adsorption is highly dependent on initial concentration of metal ion. It is because of at lower concentration, the ratio of initial number of metal ions to the available surface area is 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 metal ions adsorbed on the adsorbent surface is less.

**B. 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 metal ions on activated calcite powder surface at about 40 minutes and once again there is not a big change of amount of metal ion adsorbed with time which gives an indication that of ion exchange [17].

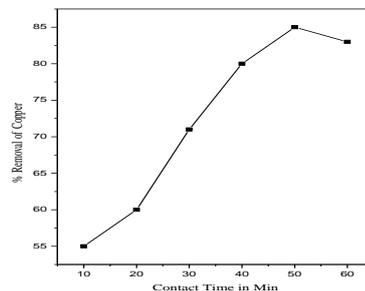


Fig-1: Effect of Contact Time on the Removal of Copper Ion [Cu]=50 mg/L; Temperature 30°C; Adsorbent dose=25mg/50ml

**C. Effect of adsorbent dosage**

The adsorbent dosage is an important parameter, which influence the extent of metal uptake from the solution. The effect of varying doses of 10 to 250 mg of AAIC was investigated using 50 mg/L of initial copper 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 [18].

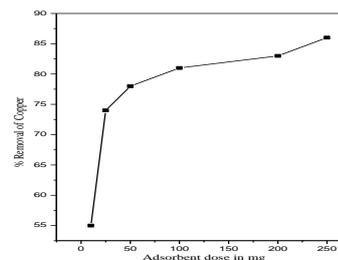


Fig-2: Effect of Adsorbent dose on the removal of Copper Ion [Cu]=50mg/L; Contact Time 60min; Temperature 30°C

**D. Effect of pH**

The experiment were carried out of different pH shows that there was a change in the quantity of adsorbed copper ions on the solid phase of activated AAIC over the entire pH range of 3 to 10 for copper shown in Fig.3. The

solution pH plays a major role in determining the amount of copper ions adsorption. The initial metal ion concentrations were kept constant. Adsorption of copper ions increased appreciably (1-2 times) with increase of pH from 3 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 metal 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 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 metal ion concentration. The other important factor, which might contribute to the higher adsorption of metal ion with increased pH, is the  $pH_{zpc}$  of AAIC. At any pH below  $pH_{zpc}$  the surface of metal oxides/ ox hydroxides 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 [19].

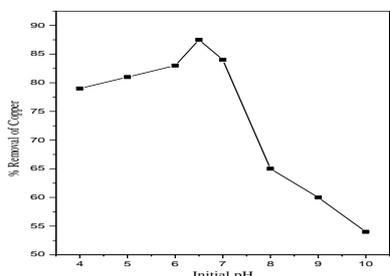


Fig.3- Effect of Initial pH on the removal of Copper Ion [Cu]=50 mg/L; Temperature 30°C; Adsorbent dose=25mg/50ml

**E. Adsorption isotherm**

**1. Freundlich isotherm**

The linear form of Freundlich isotherm [20] 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 Cu (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-II). 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 [21] (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 on activated AAIC was found to be around 5.0 L/g. The  $K_f$  values indicates that the saturation time for adsorption of metal ion is attained quickly slue to high affinity of activated AAIC towards adsorbate, while low  $K_f$  values indicates low adsorption rate of metal ion [22], [23]. The values of  $1/n$  were around 3.5 (mg/L) for copper ions. The high values of  $1/n$  signifies that the forces which are exerted on the surface of AAIC during metal ion adsorption are strong rate from the values  $K_f$  and  $1/n$  it is reveals that activated AAIC is more efficient for removal of copper ions.

**2. Langmuir isotherm**

The Langmuir isotherm model [24] 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 II). 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  $R_L$  [25], [26] 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 III). The values of  $b$  were increased with increasing the dose of adsorbent for AAIC High  $b$  values

indicate high adsorption affinity the monolayer saturation capacity  $Q_m$  were around 139 mg/L for AAIC.

**Table: II. Langmuir and Freundlich Isotherm Parameter for the Adsorption of Copper ion onto AAIC**

TEMP. (°C)	LANGUMUIR PARAMETER		FRUENDLICH 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: III. Dimensionless Separation Factor ( $R_L$ ) for the Adsorption of Copper ion onto AAIC**

(C <sub>i</sub> )	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

**F. Thermodynamic treatment of the adsorption process**

Thermodynamic parameters associated with the adsorption, via standard free energy change ( $\Delta G^0$ ), standard enthalpy change ( $\Delta H^0$ ), and standard entropy change ( $\Delta S^0$ ) 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  $\Delta G^0$  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 [27]. The adsorption distribution coefficient may be expressed in terms of enthalpy change ( $\Delta H^0$ ) and entropy change ( $\Delta S^0$ ) as a function of temperature,

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

Where  $\Delta H^0$  is the standard heat change of sorption (kJ/mol) and  $\Delta S^0$  is standard entropy change (kJ/mol). The value of  $\Delta H^0$  and  $\Delta S^0$  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 IV). The thermodynamic treatment of the sorption data indicates that  $\Delta G^0$  values were negative at all temperature. The results point out that physisorption is much more favorable for the adsorption of Cu (II) ions. The positive values of  $\Delta H^0$  show the endothermic nature of adsorption and it governs the possibility of physical adsorption. Because in the case of physical adsorption, while increasing the temperature of the system, the extent of metal ion adsorption increases,

this rules out the possibility of chemisorptions. The low  $\Delta H^0$  value depicts metal ion is physisorbed onto adsorbent AAIC.

**Table: IV. Thermodynamic Parameter for the Adsorption of Copper ion onto AAIC**

C <sub>0</sub>	$\Delta G^0$				$\Delta H^0$	$\Delta S^0$
	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

The negative  $\Delta G^0$  values (table IV) were conforming the spontaneous nature of adsorption Cu (II) ions onto AAIC. The lesser values of  $\Delta G^0$  suggest that adsorption is physical adsorption process. The positive value of  $\Delta H^0$  further confirms the endothermic nature of adsorption process. The positive values of  $\Delta S^0$  in (table IV), showed increased randomness of the solid solution interface during the adsorption of copper ion onto acid activated ipomoea carnea.

**G. 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 Cu (II) ions adsorption on the AAIC were analyzed using pseudo second-order [28] Elovich [29],[30] and intra-particle diffusion[31] kinetic models. The conformity between experimental data and the model predicted values was expressed by the correlation coefficient ( $\gamma$ ) and the values are close or equal to 1. A relatively high correlation coefficient ( $\gamma$ ) value indicates that the pseudo second-order model successfully describes the kinetics of Cu (II) ions adsorption.

**1. 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 (g mg/min). 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)(mg g<sup>-1</sup> min<sup>-1</sup>) 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) should give 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 ( $\gamma$ ) are summarized in (Table V). At all studied initial copper concentrations, the straight lines with extremely high correlation coefficient ( $>0.99$ ) were obtained. From (table V), the values of the rate constant  $k$  decrease with in increasing initial copper concentration for AAIC powder. This is shows that the sorption of Cu (II) ions on AAIC follows pseudo second order kinetic model.

**2. The Elovich equation**

The Elovich model equation is generally expressed as

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

Where;  $\alpha$  is the initial adsorption rate ( $mg\ g^{-1}\ min^{-1}$ ) and  $\beta$  is the desorption constant ( $g/mg$ ) during any one experiment. To simplify the Elovich equation. Chien and Clayton (1980) 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.(12) becomes:

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

If Cu (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  $\alpha$ ,  $\beta$ , and correlation coefficient ( $\gamma$ ) are summarized in (table V). The experimental data such as the initial adsorption rate ( $\alpha$ ) adsorption constant ( $\beta$ ) and the correlation coefficient ( $\gamma$ ) calculated from this model indicates that the initial adsorption ( $\alpha$ ) 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 AAIC adsorbent.

**3. The intra particle diffusion model**

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris [31] 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 ( $mg/g/min$ ) and  $C$  is the constant. If the rate limiting step is intra-particle diffusion, then the graph drawn between ( $q_t$ ) ( $mg/g$ ) verses square root of the contact time ( $t^{1/2}$ ) should yield a straight line passing through the origin. The slope of the will give the value of the intra-particle diffusion coefficient ( $k_{id}$ ) and correlation coefficient ( $\gamma$ ) indicate the fitness of this model. The value of  $C$  gives an idea about the thickness of the boundary layer. From these data the intercept value indicates that the line was not passing through origin, there are some other process affect the adsorption. But the correlation coefficient ( $\gamma$ ) 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 V).

**H. Evidences for adsorption**

The FT-IR spectra of the AAIC 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 AAIC and copper ion adsorbed AAIC are shown in Fig. 5a and Fig 5b. The intense main peak shows the presence of highly organized adsorbed AAIC, after the adsorption of metal 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 AAIC surface by means of physisorption.

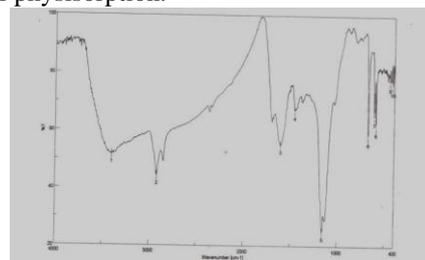


Fig.4a- FT-IR Spectrum of AAIC before adsorption

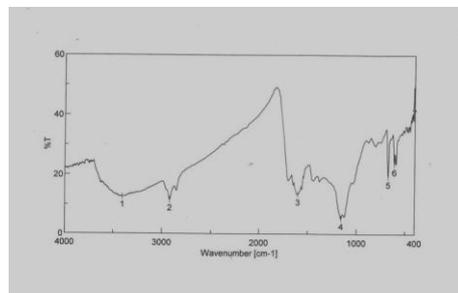


Fig. 4b- FT-IR Spectrum of AAIC after the adsorption of copper ion

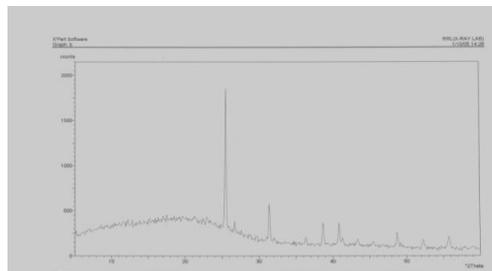


Fig.5a- XRD pattern of AAIC before adsorption

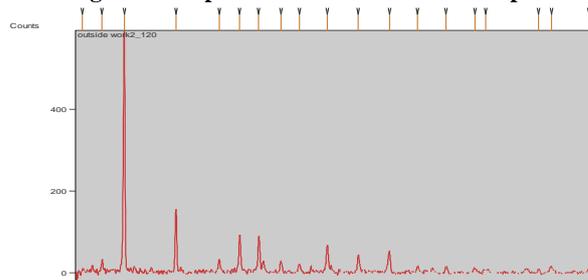


Fig.5b- XRD pattern of AAIC after the adsorption of copper ion

#### IV. CONCLUSION

From the experimental data of adsorption of Cu (II) ions onto AAIC powder surface. The following points can be concluded.

1. AAIC could be used as a potential adsorbent for the removal of Cu (II) ions from polluted water.
2. The initial pH's of aqueous solutions affect the copper ion removal. On the other hand percent removal of copper ion decreased with increasing initial concentration but increased with increasing adsorbent concentration.
3. From the experimental data's obtained shows that the adsorption of Cu (II) ions on to AAIC well fit with Freundlich isotherm and Langmuir isotherm.
4. The adsorption of Cu (II) ions on to activated AAIC shows negative  $\Delta G^\circ$  values this indicates sorption process is physisorption.
5. The sorption of Cu (II) ions on AAIC follows pseudo second order kinetic model and it is controlled by intra-particle diffusion.
6. The removal percentage of Cu (II) ions by the new adsorbent is fairly high. The mechanism of adsorption of copper ion onto AAIC is confirmed by FT-IR and XRD studies.

#### V. ACKNOWLEDGEMENT

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Table: I. Equilibrium Parameters for the Adsorption of Copper ion onto AAIC

Cu <sub>0</sub>	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	2.28	2.00	1.90	1.86	45.43	45.98	46.19	46.27	90.86	91.97	92.38	92.54
50	7.62	6.82	5.03	5.02	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: V. The Kinetic Parameters for the Adsorption of Copper ion onto AAIC

Cu <sub>0</sub>	Temp °C	Pseudo Second Order				Elovich Model			Intraparticle Diffusion		
		q <sub>e</sub>	K <sub>2</sub>	γ	h	α	β	γ	K <sub>id</sub>	γ	C
25	30	49.74	22×10 <sup>-3</sup>	0.9940	7.13	131.18	0.16	0.9921	1.67	0.9924	0.15
	40	50.51	21×10 <sup>-3</sup>	0.9953	6.90	106.12	0.15	0.9914	1.66	0.9942	0.15
	50	50.42	20×10 <sup>-3</sup>	0.9971	7.67	108.16	0.15	0.9931	1.67	0.9914	0.16
	60	51.07	21×10 <sup>-3</sup>	0.9991	7.59	83.62	0.14	0.9954	1.66	0.9923	0.17
50	30	93.40	26×10 <sup>-3</sup>	0.9984	12.74	148.53	0.07	0.9912	1.61	0.9918	0.16
	40	95.02	25×10 <sup>-3</sup>	0.9975	13.91	186.05	0.07	0.9961	1.64	0.9924	0.16
	50	98.49	23×10 <sup>-3</sup>	0.9983	13.91	164.46	0.07	0.9943	1.64	0.9917	0.16
	60	96.68	21×10 <sup>-3</sup>	0.9997	16.32	386.72	0.08	0.9917	1.68	0.9934	0.14
75	30	133.37	29×10 <sup>-3</sup>	0.9965	15.91	116.23	0.05	0.9981	1.55	0.9917	0.19
	40	135.79	28×10 <sup>-3</sup>	0.9974	17.90	151.67	0.05	0.9917	1.58	0.9920	0.18
	50	137.83	26×10 <sup>-3</sup>	0.9963	19.82	223.49	0.05	0.9937	1.61	0.9916	0.16
	60	140.48	25×10 <sup>-3</sup>	0.9946	16.55	313.88	0.05	0.9928	1.63	0.9914	0.15
100	30	162.73	33×10 <sup>-3</sup>	0.9958	15.65	69.51	0.03	0.9914	1.43	0.9911	0.23
	40	161.48	29×10 <sup>-3</sup>	0.9919	19.07	136.86	0.04	0.9925	1.50	0.9921	0.19
	50	166.34	14×10 <sup>-3</sup>	0.9946	19.34	134.12	0.03	0.9916	1.51	0.9934	0.19
	60	169.47	29×10 <sup>-3</sup>	0.9986	22.27	186.01	0.04	0.9935	1.55	0.9921	0.18
125	30	180.05	31×10 <sup>-3</sup>	0.9975	17.11	73.20	0.03	0.9974	1.37	0.9932	0.23
	40	184.86	30×10 <sup>-3</sup>	0.9977	18.84	100.31	0.03	0.9941	1.42	0.9922	0.21
	50	195.69	21×10 <sup>-3</sup>	0.9980	17.76	70.63	0.02	0.9913	1.39	0.9981	0.24
	60	195.94	31×10 <sup>-3</sup>	0.9974	20.71	102.35	0.03	0.9924	1.44	0.9954	0.21

**AUTHOR'S PROFILE**



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