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Adsorption mechanism of Cu(II) ion Removal from Aqueous Solution using Acid Activated Madhuca longifolia Stem

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ABSTRACT

The series of batch laboratory experiment were carried out by using Acid Activated Madhuca longifolia Stem Carbon for the removal of Cu (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 Cu (II). 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 Cu (II) ions, i.e. > 90% has been achieved in aqueous solutions using 0.025g of AMLSC at a pH of 6.6. The kinetic process of Copper AMLSC was described by applying pseudo second order rate equation, Elovich model and intra- particles diffusion. The activated AMLSC investigated in this study carries high potential for the removal of Cu (II) ions from aqueous solution. The various thermodynamic parameters like ΔG^O, ΔH^O, and ΔS^O and were analyzed to observe the nature of adsorption.

Keywords: Cu (II), AMLSC adsorbent, batch adsorption, adsorption isotherms, 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]. Wastewater quality can be defined by physical, chemical or biological characteristics. Wastewater generally contains toxic inorganic and organic pollutants. Inorganic pollutants consist of mineral acids, inorganic salts, finely divided metal compounds, trace elements, cyanides, nutrients and organ metallic compounds. Some of the trace elements play essential roles in biological processes, but at higher concentrations, they may be toxic to the biota; they disturb the biochemical processes and cause hazards. These elements include metals (Cd, Cr, Co, Fe, Cu, Zn, Pd, Hg, Ni, and Ag) and metalloids (Se, As, Sb). Most of the trace elements are transition metals with variable oxidation states and coordination numbers. These metals form complexes with organics in the environment thereby increasing their mobility in the biota and manifest toxic effects. Although there are metals that have inherent ability to antagonize the essential functions of other elements, the heavy load of contaminants arising from human activity exceeds the ability of self-purification of aqueous environment.

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, chemical and electrochemical techniques and adsorption processes 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.

The present study undertaken to evaluate the efficiency of an adsorbent prepared from Acid Activated Madhuca Longifoliafor removal of Cu(II) ion in aqueous solution. In order to design adsorption treatment systems, knowledge of kinetic and mass transfer processes is essential. In this work, the applicability of kinetic and mass-transfer models for the adsorption of Cu(II) ion onto Acid Activated Madhuca Longifolia was discussed in detailed manner.

II. METHODS AND MATERIAL

2.1. Adsorbent

The Madhuca longifolia Stem obtained from nearby Perambalur district the stem was Carbonized with concentrated Sulphuric acid and washed with water and activated around 600°C in a muffle furnace for 5 hrs the it was taken out, ground well to fine powder and stored in a vacuum desiccators.

2.2. Chemicals

All chemicals used of high purity commercially available Analar grade. 1000 mg/L of stock solution of Copper (II) ($CuSO_4$ 5 H_2O) was prepared by calculated quantity weighed of Ammonium Iron (III) sulfate 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 Cu(II) was determined with atomic absorption spectrophotometer (Perkin Elemer 2380).

2.3. Batch experiments

The effect of various parameters on the removal of Cu(II) onto AMLSC was studied batch adsorption experiments were conducted at (30-60°C). For each experimental run, 50 ml of Cu(II) 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 Cu(II) concentration[15].

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

Adsorption equilibrium isotherm is studied using 25 mg of AMLSC dosage per 50 ml of Cu(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 Cu(II) concentration. The adsorption capacity was calculated by using a mass equilibrium equation as follows:

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

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

$$\%R = (C_0 - C_t)\ x\ 100/C_0 \ldots\ldots\ldots\ldots\ldots\ (2)$$

The effect of pH on the rate of adsorption was investigated using Cu (II) concentration of 75 mg/L constant AMLSC 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 Cu (II) in solution was determined.

2.4. 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 Cu (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.

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

III. RESULT AND DISCUSSION

3.1 Characteristics of the adsorbent

Acid Activated Madhuca Longifolia is an effective adsorbent for the abatement of many pollutant compounds (organic, inorganic, and biological) of concern in water and wastewater treatment. Most of the solid adsorbents possess micro porous fine structure, high adsorption capacity, high surface area and high degree of surface, which consists of pores of different sizes and shapes[17]. The wide usefulness of AMLSC is a result of their specific surface area, high chemical and mechanical stability. The chemical nature and pore structure usually determines the sorption activity. The physico-chemical properties of the chosen adsorbent are listed in Table 1.

Table 1 : Characteristics of the Adsorbent

Properties	AMLSC
Particle size(mm)	0.015
Density (g/cc)	0.2025
Moisture content (%)	0.1827
Loss in ignition (%)	0.013
pH of aqueous solution	6.300

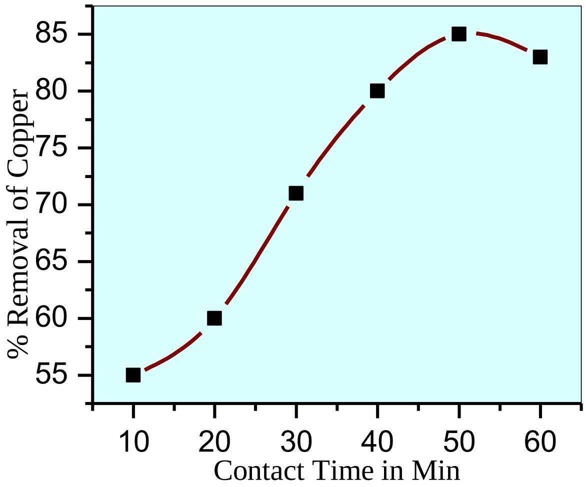


Fig:1- Effect of Contact Time on the Removal of Cu(II) Ion [Cu]=50 mg/L;Temprature 30°C;Adsorbent dose=25mg/50ml

3.2 Effect of initial concentration

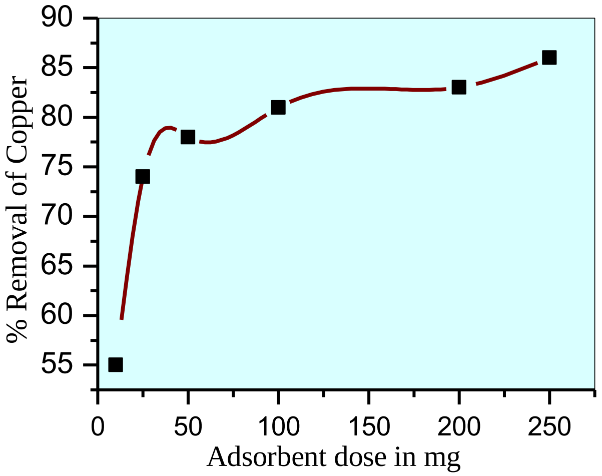
The experimental results of adsorption of Cu(II) ions on AMLSC at various initial concentration (25, 50, 75, 100 and 125 mg/L) for Cu(II) ions in terms of equilibrium data are given in table.2. It reveals that, the actual amount of Cu(II) ions adsorbed per unit mass of AMLSC increased with increase in 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.

3.3. Effect of contact time

The effect of contact time on the adsorption of Cu(II) 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 AMLSC 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[18].

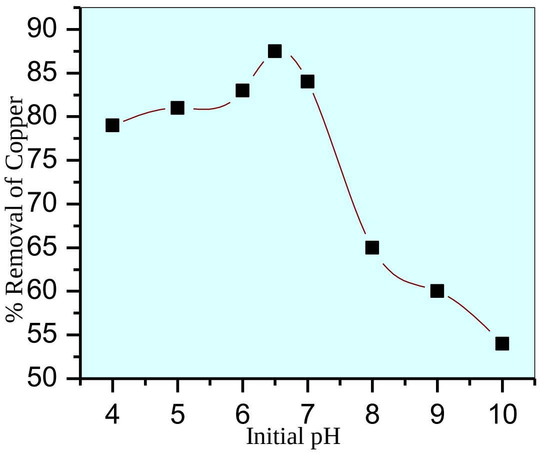
3.4 Effect of adsorbent dosage

The adsorbent dosage is an important parameter, which influence the extent of metal uptake from the solution. The effect of varying doses of 25 to 125 mg of AMLSC was investigated using 50 mg/L of initial Cu(II) concentration at initial pH 6.5 shows an increase in percentage removal of Cu(II) 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[19].



Fig;2- Effect of Adsorbent dose on the removal of Cu(II) Ion
[Cu]=50mg/L;Contact Time 60min;Temprature 30^{0}C

3.5 Effect of pH



Fig;3- Effect of Initial pH on the removal of Cu(II) Ion
[Cu]=50 mg/L;Temprature 30^{o}C;Adsorbent dose=25mg/50ml

The experiment were carried out of different pH shows that there was a change in the quantity of adsorbed Cu(II) ions on the solid phase of activated AMLSC over the entire pH range of 3 to 10 for Cu(II) shown in Fig.3. The solution pH plays a major role in determining the amount of Cu(II) ions adsorption. The initial metal ion concentrations were kept constant. Adsorption of Cu(II) 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

$$M^{2+} + nH_2O \quad \square \quad M(OH)_n^{2-n} + nH^+$$

and taking only primary metal species expected to be formed in the working pH range into consideration, the species distribution diagrams for Cu(II) ion is constructed and given in Fig. 3, It is evident that Fe^{3+} 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 Cu(II) ion. Since maximum adsorption Cu(II) ion was achieved at pH ~ 6.5, it may safely be stated that the removal of Cu(II) ion was mostly due to adsorption and not precipitation. However, precipitation of small fractions of Fe^{3+} even at pH ~ 6.5 on the surface by nucleation cannot be neglected. At still higher pH (>7), however, part of Fe^{3+} 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_{pzc} of AMLSC. At any pH below pH_{pzc} the surface of metal oxides/ oxyhydroxides is positively charged and at pH above pH_{pzc} 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[20].

3.6 Adsorption isotherm

3.6.1 Freundlich isotherm

The linear form of Freundlich isotherm[20]is represented by the equation

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

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-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[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 Cu(II) on activated AMLSC 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 AMLSC 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 Cu(II) ions. The high values of 1/n signifies that the forces which are exerted on the surface of AMLSC during metal ion adsorption are strong rate from the values K_f and 1/n it is reveals that activated AMLSC is more efficient for removal of Cu(II) ions.

3.6.2 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

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

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[25, 26] by the equation

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

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 AMLSC High b values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 139 mg/L for AMLSC.

3.7. 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

$$\Delta G^\circ = -RT \ln K_0 \ldots\ldots\ldots \;(7)$$

Where ΔG° 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_O 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 (ΔH°) and entropy change (ΔS°) as a function of temperature

$$ln\ K_o = \left(\Delta H^o / RT\right) + \left(\Delta S^o / R\right) \ldots\ldots\ldots..(8)$$

Where ΔH° is the standard heat change of sorption (kJ/mol) and ΔS° is standard entropy change (kJ/mol). The value of ΔH° and ΔS° 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° 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 ΔH° show the endothermic nature of adsorption and it governs the possibility of physical adsorption[23]. 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 [23, 24]. The low ΔH° value depicts metal ion is physisorbed onto adsorbent AMLSC.

The negative ΔG° values table 4 were conform the spontaneous nature of adsorption Cu(II) ions onto AMLSC. The lesser values of ΔG° suggest that adsorption is physical adsorption process. The positive value of ΔH° further confirms the endothermic nature of adsorption process. The positive values of ΔS° in table 4, showed increased randomness of the solid solution interface during the adsorption of Cu(II) ion onto acid activated abutilon indicum.

3.8. 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 AMLSC 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 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 Cu(II) ions adsorption.

3.8.1 The pseudo second- order equation

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

$$dq_t / d_t = k_2 \left(q_e - q_t\right)^2 \ldots\ldots\ldots\ldots..(9)$$

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:

$$1/\left(q_e - q_t\right) = 1/q_e + K_2 t \ \ldots\ldots\ldots\ldots\ldots\ldots.\ (10)$$

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:

$$t/q_t = \left(1/k_2 q_e^{\,2}\right) + \ ((1/q_e)t \ldots\ldots\ldots\ldots\ldots\ldots..(11)$$

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

$$h = k_2 q_e^{\,2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\left(12\right)$$

Equation (9) and (10) becomes

$$t/q_t = 1/h + 1/q_e t \ \ldots\ldots\ldots\ldots\ldots\ \ldots\left(13\right)$$

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 (γ) are summarized in Table (5).At all studied initial Cu(II) 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 in increasing initial Cu(II) concentration for AMLSC carbon. This is shows that the sorption of Cu(II) ions on AMLSC follows pseudo second order kinetic model[32.]

3.8.2 The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / d_t = \alpha \; exp \; (-\beta q_t) \ldots\ldots..(14)$$

Where; α is the initial adsorption rate (mg g^{-1} min^{-1}) and β is the desorption constant (g/mg) during any one experiment. To simplify the Elovich equation. Chien and Clayton (1980) assumed αβt>>t and by applying boundary conditions $q_t = 0$ at t= 0 and $q_t = q_t$ at t = t Eq.(12) becomes:

$$q_t = 1/\beta \ln \; (a\beta) \; + \; 1/\beta \ln \; t \; \ldots\ldots\ldots\ldots\ldots \; (15)$$

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/β)and an intercept of (1/β)ln (αβ). 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 AMLSC adsorbent.

3.8.3 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:

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

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[31]. The slope of the will give 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. From these data the intercept value indicate that the line were 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.

IV. CONCLUSION

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

1. AMLSC 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 Cu (II) ion removal. On the other hand percent removal .of Cu (II) 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 AMLSC well fit with Freundlich isotherm and Langmuir isotherm.
4. The adsorption of Cu (II) ions on to activated AMLSC shows negative ΔG° values this is indicates sorption process is physisorption.
5. The sorption of Cu (II) ions on AMLSC 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.

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TABLE: 2. EQUILIBRIUM PARAMETERS FOR THE ADSORPTION OF Cu(II) ION ONTO AMLSC

C_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	2.249	1.749	1.499	1.474	15.50	16.50	17.00	17.05	77.51	82.51	85.01	85.26
50	3.749	3.500	3.259	2.749	32.50	33.00	33.48	34.50	81.26	82.50	83.70	86.25
75	7.019	6.450	5.749	5.400	45.96	47.10	48.50	49.20	76.60	78.50	80.84	82.00
100	9.770	9.020	8.607	8.136	60.46	61.96	62.79	63.73	75.58	77.45	78.48	79.66
125	14.00	13.55	13.27	12.54	72.00	72.90	73.46	74.92	72.00	72.90	73.46	74.92

TABLE: 3. LANGMUIR AND FREUNDLICH ISOTHERM PARAMETER FOR THE ADSORPTION OF Cu(II) ION ONTO AMLSC

TEMP. (^{0}C)	LANGUMUIR PARAMETER		FRUENDLICH PARAMETER	
	Q_m	b	K_f	n
30°	188.75	0.0461	9.310	1.2372
40°	143.13	0.0792	11.976	1.3783
50°	126.84	0.1076	13.951	1.4721
60°	127.55	0.1176	14.985	1.4803

TABLE: 4. DIMENSIONLESS SEPERATION FACTOR (R_L) FOR THE ADSORPTION OF Cu(II) ION ONTO AMLSC

(C_i)	TEMPERATURE °C			
	30°C	40°C	50°C	60°C
25	0.464	0.336	0.271	0.254
50	0.302	0.202	0.157	0.145
75	0.224	0.144	0.110	0.102
100	0.178	0.112	0.085	0.078
125	0.148	0.092	0.069	0.064

TABLE: 5. THERMODYNAMIC PARAMETER FOR THE ADSORPTION FOR THE ADSORPTION OF Cu(II) ION ONTO AMLSC

C_0	ΔG°				ΔH°	ΔS°
	30° C	40° C	50° C	60° C		
25	-3117.3	-4037.3	-4659.4	-4859.6	14.71	59.39
50	-3694.9	-4035.2	-4394.3	-5084.4	9.957	44.84
75	-2987.6	-3370.2	-3865.6	-4198.2	9.537	41.33
100	-2845.5	-3211.0	-3474.8	-3779.7	6.449	30.74
125	-2379.5	-2575.7	-2733.7	-3029.1	3.982	20.95

TABLE: 6. THE KINETIC PARAMETERS FOR THE ADSORPTION OF Cu(II) ION ONTO AMLSC

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**	15.712	0.0160	0.9940	3.947	7.072	3.562	0.9921	0.018	0.9924	1.8780
	40	17.812	0.0097	0.9953	3.069	8.244	4.787	0.9914	0.141	0.9942	1.6600
	50	17.784	0.0165	0.9971	5.204	4.028	7.172	0.9931	0.088	0.9914	1.7693
	60	17.787	0.0175	0.9991	5.551	7.655	7.557	0.9954	0.083	0.9923	1.7797
50	**30**	35.883	0.0034	0.9984	4.406	4.530	2.003	0.9912	0.176	0.9918	1.5833
	40	36.129	0.0038	0.9975	4.980	6.718	2.097	0.9961	0.164	0.9924	1.6144
	50	36.482	0.0044	0.9983	5.792	1.077	2.201	0.9943	0.151	0.9917	1.6478
	60	36.976	0.0049	0.9997	6.706	2.520	2.427	0.9917	0.132	0.9934	1.6925
75	**30**	48.989	0.0037	0.9965	8.901	6.177	1.997	0.9981	0.120	0.9917	1.6583
	40	50.715	0.0040	0.9974	10.41	5.072	1.837	0.9917	0.126	0.9920	1.6708
	50	52.742	0.0034	0.9963	9.519	2.174	1.576	0.9937	0.144	0.9916	1.6514
	60	52.347	0.0050	0.9946	13.62	8.905	1.856	0.9928	0.119	0.9914	1.7070
100	**30**	64.923	0.0037	0.9958	15.50	5.154	1.362	0.9914	0.132	0.9911	1.6501
	40	66.417	0.0035	0.9919	15.22	5.212	1.336	0.9925	0.132	0.9921	1.6582
	50	67.063	0.0037	0.9946	16.59	7.149	1.369	0.9916	0.127	0.9934	1.6746
	60	68.023	0.0037	0.9986	17.08	8.181	1.370	0.9935	0.124	0.9921	1.6850
125	**30**	76.944	0.0022	0.9975	12.80	4.698	1.162	0.9974	0.133	0.9932	1.6061
	40	77.993	0.0021	0.9977	12.91	4.677	1.145	0.9941	0.133	0.9922	1.6112
	50	78.162	0.0023	0.9980	13.94	7.661	1.212	0.9913	0.124	0.9981	1.6313
	60	79.910	0.0021	0.9974	13.36	5.335	1.133	0.9924	0.131	0.9954	1.6260