

MECHANISTIC STUDIES OF COPPER (II) ION ADSORPTION ON ACTIVATED PONGAMIA PINNATA SHELL NANO CARBON

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ABSTRACT

An adsorbent prepared from *Pongamia pinnata* Shell, by acid treatment was tested for its efficiency in removing copper ion. The process parameters studied include agitation time, initial copper (II) ion concentration, adsorbent dose, pH and temperature. The adsorption followed second order reaction equation and the rate is mainly controlled by intra-particle diffusion. Freundlich and Langmuir isotherm models were applied to the equilibrium data. The adsorption capacity (Q_m) obtained from the Langmuir isotherm plot at an initial pH of 6.5 and at 30, 40, 50, 60 \pm 0.5 $^{\circ}$ C. The influence of pH on copper (II) ion removal was significant and the adsorption was increased with increase in temperature. A portion of the copper (II) ion was recovered from the spent APPSNC using 0.1M HCl.

Keywords: Acid Activated Pongamia pinnata Shell Nano Carbon (APPSNC), copper (II) ion, Adsorption isotherm, Equilibrium, Thermodynamic parameters, Intra-particle diffusion.

INTRODUCTION

Heavy metal pollution of water and water bodies is a serious environmental problem that affects the quality of water. The consequences are decreasing water supply, increase in cost of purification, eutrophication of water bodies and decrease in aquatic production [1]. In order to tackle the menace posed by heavy metal pollution of water, several options have been adopted. These include oxidation and reduction, chemical precipitation, filtration,

electrochemical treatment, ion exchange, membrane separation, reverse osmosis, adsorption, evaporation and electrolysis [2]. However, adsorption has been proven to be one of the best options available for the removal of heavy metals from aqueous solution [3, 4]. In view of the above, several researches have been conducted using various materials as adsorbents [5]. However, some of these adsorbents also contain other toxicants; some are expensive and are characterized with limited surface area for adsorption. A search of literature revealed that fruit stone has been used for adsorption of some heavy metals from aqueous solution but literature is scanty on the use of activated carbon produced from fruit stone for the adsorption of Pb (II) and copper (II) ions from aqueous solution. Therefore, the objective of the present study is to investigate the possibility of using APPSNC as an adsorbent for the removal of copper (II) ions from aqueous solution.

MATERIALS AND METHODS

Preparation of Adsorbent

The *Pongamia pinnata* Shell collected from nearby Thiruvapur district was carbonized with concentrated Sulphuric acid and washed with water and activated around 1100 $^{\circ}$ C in a muffle furnace for 6 hrs then it was taken out, ground well to fine powder and stored in a vacuum desiccators.

Chemicals

All chemicals used of high purity commercially available Analar grade. 1000 mg/L of stock solution of



Copper (II) was prepared by dissolving accurately weighed 3.9296 gram of Copper (II) sulphate pentahydrate 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 UV-visible spectrophotometer (Systronics 2203).



Figure 1. *Pongamia pinnata* Shell

Batch Experiments

The effect of various parameters on the removal of copper (II) ion onto APPSNC was studied batch adsorption experiments were conducted at (30-60 °C). For each experimental run, 50 ml of Copper (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 (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) ion concentration.

The effect of dosage of adsorbent on the removal of copper (II) ion was measured by contacting 50 ml of 50 mg/L of copper (II) ion solution with 25 mg to 125 mg of APPSNC till equilibrium was attained. Adsorption equilibrium isotherm is studied using 25 mg of APPSNC dosage per 50 ml of copper (II) ion 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) ion 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) ion percentage can be calculated as follows:

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

The effect of pH on the rate of adsorption was investigated using Copper (II) concentration of 25 mg/L constant APPSNC 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 50 minutes. Then the concentration of copper (II) ion solution was determined.

RESULTS AND DISCUSSION

Effect of agitation time and initial Copper (II) ion concentration

The kinetics of adsorption of copper (II) ion by APPSNC is shown in (fig. 1) with smooth and single plots indicating monolayer adsorption of copper (II) ion on the APPSNC. The removal of copper (II) ion increased with the lapse time and attains equilibrium in 60 min for 50 mg/ L. With increase in copper (II) ion concentration from 25 to 125 mg/L, the amount of copper (II) ion adsorbed increased while the percent removal decreased, The experimental results of adsorptions at different concentrations collected in Table 1 observed that percent adsorption decreased with increase in initial indicating that the copper (II) ion removal by adsorption on APPSNC concentration dependent[6].

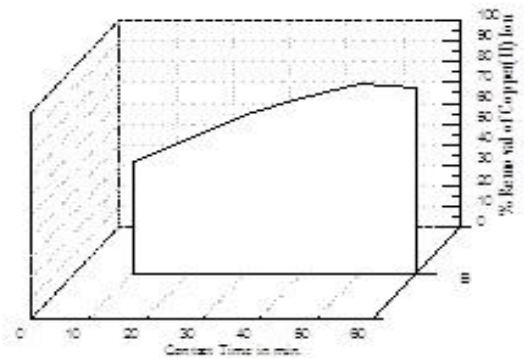


Figure 2. Effect of contact time on the adsorption of copper ion [Cu] = 50 mg/L; adsorbent dose=25 mg/50 mL; temp=30°C

Effect of APPSNC mass

The amount of copper (II) ion adsorption increased with the increase in APPSNC dose and reached a maximum value after a particular dose (fig.2). Taken an initial copper (II) ion concentration of 50 mg/L, complete copper (II) ion removal was obtained at a maximum APPSNC dose of 125 mg. The increase in the adsorption of copper (II) ion with APPSNC dose was due to the introduction of more binding sites for adsorption and the availability more surface area [7].



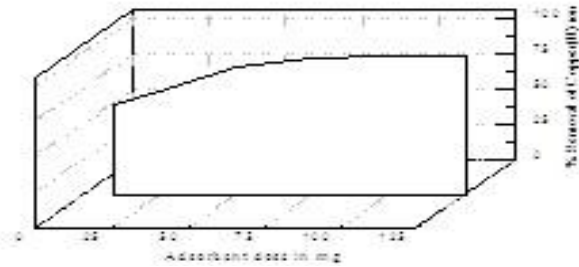


Figure 3. Effect of adsorbent dose on the removal of copper ion [Cu] = 50 mg/L; temp=30°C; contact time = 50 min; pH=6.3

Effect of pH:

The experience carried out at different pH show that there was a change in the percent removal of copper (II) ion over the entire pH range shown in Fig. 3. This indicates the strong force of interaction between the copper (II) ion and APPSNC that either H⁺ or OH⁻ ions could influence the adsorption capacity. In other words, the adsorption of copper (II) ion on APPSNC does involve ion exchange mechanism that have been an influence on the copper (II) ion adsorption while varying the pH. This observation is in line with the type I and II isotherm and positive ΔH⁰ value obtained, which indicates irreversible adsorption probably due to polar interactions [8].

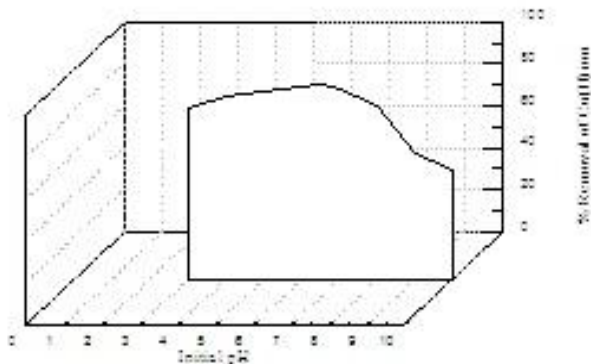


Figure 4. Effect of initial pH on the adsorption of copper ion [Cu] = 50 mg/L; temp=30°C; Adsorbent dose = 50 mg/50 ml

Effect of other ions:

The effect of other ions like Ca²⁺ and Cl⁻ on the adsorption process studied at different concentrations. The ions added to 50mg/L of copper (II) ion solutions and the contents were agitated for 60 min at 30°C. The low concentration of Cl⁻ does not affect the percentage of adsorption of copper (II) ion on APPSNC, because the interaction of Cl⁻ at available sites of adsorbent through competitive adsorption is not so effective. While the concentration of other ion Ca²⁺ increases, the interference of these ions at available surface sites of the sorbent

through competitive adsorption increases that, decreases the percentage adsorption. The interference was more in the presence of Ca²⁺ compared with Cl⁻ ion. This is so because ions with smaller hydrated radii decrease the swelling pressure within the sorbent and increase the affinity of the sorbent for such ions [9].

Effect of temperature:

The adsorption capacity of APPSNC increased with increase in the temperature of the system from 30 to 60 °C. Thermodynamic parameters such as change in free energy (ΔG⁰), enthalpy (ΔH⁰) and entropy (ΔS⁰) were determined using the following equations.

$$K_0 = C_{solid}/C_{liquid} \dots\dots\dots (3)$$

$$\Delta G^0 = -RT \ln K_0 \dots\dots\dots (4)$$

$$\log K_0 = \Delta S^0/(2.303R) - \Delta H^0/(2.303RT).. (5)$$

Where, K₀ is the equilibrium constant, C_{solid} is the solid phase concentration at equilibrium (mg/L), C_{liquid} is the liquid phase concentration at equilibrium (mg/L), T is the temperature in Kelvin and R is the gas constant. ΔH⁰ and ΔS⁰ were obtained from the slope and intercept of van't Hoff plot and are presented in Table 4. Positive value of ΔH⁰ shows the endothermic nature of adsorption. This rules the possibility of both physical as well as chemical adsorption. Because in the case of physical adsorption alone, while increasing the temperature of the system the extent of copper (II) ion adsorption decreases, as desorption increases with temperature. As chemisorptions is mainly an irreversible process, the low positive ΔH⁰ value depicts that Copper (II) ion is both physically as well as chemically adsorbed onto APPSNC. This is in agreement with the type I and II isotherm obtained, which is close to irreversible adsorption [10].

The negative values of ΔG⁰ (Table 4) indicate that the copper (II) ion adsorption is spontaneous. The positive value of ΔS⁰ shows increased randomness at the solid-solution interface during the adsorption of copper (II) ion on APPSNC. The adsorbed water molecules, which are displaced by the adsorbate species, gain more translational entropy than is lost by the adsorbate molecules thus allowing the prevalence of randomness in the system. Enhancement of adsorption capacity of APPSNC at higher temperatures may be attributed the enlargement of pore size and/or activation of the adsorbent surface [11].

ADSORPTION ISOTHERMS

Freundlich isotherm

The linear form of Freundlich isotherm [12] is represented by the equation

$$\log q_e = \log K_f + (1/n)\log C_e \dots\dots\dots (6)$$

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 coefficient K_f of Copper (II) on APPSNC was found to be around 2.0 L/g. The K_f values indicates that the saturation time for adsorption of copper (II) ion is attained quickly due to high affinity of APPSNC towards adsorbate, while low K_f values indicates low adsorption rate of copper ion [13]. The values of $1/n$ were around 3.0 (mg/L) for copper (II) ions. The high values of $1/n$ signifies that the forces which are exerted on the surface of APPSNC during copper (II) ion adsorption are strong rate from the values K_f and $1/n$ it is reveals that APPSNC is more efficient for removal of copper (II) ions.

Langmuir isotherm

The Langmuir isotherm model [14] 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

$$C_e/q_e = (1/Q_m b) + (C_e/Q_m) \dots\dots\dots(7)$$

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 [15] By the equation

$$R_L = (1/(1+bC_o)) \dots\dots\dots(8)$$

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 concentration of copper (II) ion. High 'b' values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 393 mg/L for APPSNC.

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

$$\Delta G^0 = -RT \ln K_0 \dots\dots\dots(9)$$

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 [16]. The adsorption distribution coefficient may be expressed in terms of enthalpy change (ΔH^0) and entropy change (ΔS^0) as a function of temperature,

$$\ln K_0 = (\Delta H^0/RT) + (\Delta S^0/R) \dots\dots(10)$$

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 9 and 10 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 [17]. 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 APPSNC.

The negative ΔG^0 values table 4 were conform the spontaneous nature of adsorption copper (II) ions onto APPSNC. 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 APPSNC.



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 [18]. The kinetics of copper (II) ions adsorption on the APPSNC 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 coefficient (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

$$dq_t/dt = k_2(q_e - q_t)^2 \dots\dots\dots(11)$$

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. (11) becomes:

$$1/(q_e - q_t) = 1/q_e + k_2 t \dots\dots\dots(12)$$

This is the integrated rate law for a pseudo second-order reaction. Equation (12) can be rearranged to obtain Eq.(13), which has a linear form:

$$t/q_t = (1/k_2 q_e^2) + ((1/q_e)t) \dots\dots\dots(13)$$

If the initial adsorption rate (h)(mg g⁻¹min⁻¹) is :

$$h = k_2 q_e^2 \dots\dots\dots(14)$$

Equation (11) and (12) becomes,

$$t / q_t = 1 / h + 1 / q_e t \dots\dots\dots(15)$$

The plot of (t/q_t) and t of Eq. (15) gives a linear relationship from which q_e and k₂ can be determined from the slope and intercept of the plot, respectively. The pseudo-second order rate constants k₂, the calculated h values, and the correlation coefficients (γ) are summarized in Table 5. At all studied initial copper (II) ion 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 (II) ion concentration for APPSNC. This shows that the sorption of copper (II) ions on APPSNC follows pseudo second order kinetic model.

The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / d_t = \alpha \exp (-\beta q_t) \dots\dots\dots(16)$$

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 [19] 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.(16) becomes:

$$q_t = 1/\beta \ln (\alpha\beta) + 1/\beta \ln t \dots\dots\dots(17)$$

Since, copper (II) ions adsorption fits with the Elovich model, a plot of q_t vs. $\ln(t)$ yields 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 APPSNC adsorbent.

The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris [20] based on the following equation for the rate constant:

$$q_t = k_{id} t^{(1/2)} + C \dots\dots\dots(18)$$

Where, k_{id} is the intra-particle diffusion rate constant (mg/g/min) and ‘C’ is the constant. Since the rate limiting step is intra-particle diffusion, the graph drawn between (q_t) (mg/g) verses square root of the contact time ($t^{1/2}$) yields a straight line passing through the origin. The slope 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 lines 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.

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the copper (II) ions. If the adsorbed copper (II) ions can be desorbed using neutral pH water, then the attachment of the copper (II) ion of the adsorbent is by weak bonds. The effect of various reagents used for desorption studies. The results indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 90% removal of adsorbed copper (II) ion. The reversibility of adsorbed copper (II) ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of copper (II) ion by mineral acids and alkaline medium indicates that the copper (II) ion was adsorbed onto the APPSNC through physisorption as well as by chemisorptions mechanisms.



Table 1. Equilibrium parameters for the adsorption of Copper (II) Ion onto APPSNC

M ₀	Ce (mg / L)				Qe (mg / L)				Removal %			
	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	3.852	3.634	3.732	3.005	92.39	92.72	92.53	93.98	92.391	92.726	92.534	93.98
50	14.26	12.36	10.73	9.083	171.4	175.2	178.5	181.83	85.736	87.635	89.269	90.91
75	30.36	27.64	23.09	20.68	239.2	244.7	253.8	258.6	79.754	81.568	84.602	86.20
100	58.62	54.09	23.09	44.70	282.7	291.8	353.8	310.5	70.686	72.953	88.451	77.64
125	90.67	85.68	49.06	74.68	318.6	328.6	401.8	350.6	63.731	65.725	80.374	70.12

Table 2. Langmuir and Freundlich Isotherm parameter for the adsorption of Copper (II) Ion onto APPSNC

Temp.(°C)	Langmuir Parameters		Freundlich Parameters	
	Q _m	b	K _f	n
30 °C	367.728	0.0703	1.7546	2.5540
40 °C	373.392	0.0753	1.4781	2.4949
50 °C	574.084	0.0464	1.6440	1.6586
60 °C	392.876	0.0940	1.8278	2.4678

Table 3. Dimensionless separation factor (R_L) for the adsorption of Copper (II) Ion onto APPSNC

(C _i)	Temperature °C			
	30°C	40°C	50°C	60°C
25	0.2851	0.2045	0.3011	0.1753
50	0.1244	0.1758	0.1542	0.0870
75	0.0545	0.0812	0.1875	0.0661
100	0.0663	0.0651	0.0972	0.0504
125	0.0538	0.0541	0.0793	0.0407

Table 4. Thermodynamic parameter for the adsorption of Copper (II) Ion onto APPSNC

(C ₀)	ΔG ⁰				ΔH ⁰	ΔS ⁰
	30 °C	40 °C	50 °C	60 °C		
25	-6549.62	-6841.7	-6759.89	-7612.5	7.0597	40.442
50	-4558.22	-5096.11	-5689.3	-6377.31	14.871	61.567
75	-3546.76	-3850.54	-4575.28	-5074.15	13.540	55.510
100	-2417.31	-2582.12	-5467.31	-3447.26	18.542	68.618
125	-1440.07	-1694.32	-3786.12	-2362.47	13.548	51.254

Table 5. The kinetic parameters for the adsorption of Copper (II) Ion onto APPSNC

C 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	102.155	0.0021	0.992	14.012	134.90	0.0694	0.994	0.1771	0.998	1.6461
	40	100.410	0.0019	0.994	16.289	427.67	0.0846	0.995	0.1416	0.991	1.7065
	50	99.859	0.0018	0.991	17.751	744.47	0.0913	0.997	0.1298	0.993	1.7284
	60	101.595	0.0017	0.992	17.506	401.61	0.0818	0.999	0.1446	0.992	1.7105
50	30	188.478	0.0025	0.991	26.669	297.98	0.0387	0.998	0.1705	0.991	1.6238
	40	192.254	0.0024	0.992	27.236	353.65	0.0391	0.997	0.1647	0.992	1.6411
	50	195.115	0.0023	0.991	29.749	442.24	0.0395	0.998	0.1590	0.991	1.6622
	60	197.295	0.0021	0.993	32.326	712.14	0.0418	0.992	0.1462	0.993	1.6921
75	30	265.768	0.0028	0.991	33.590	302.95	0.0263	0.994	0.1812	0.997	1.5714
	40	269.832	0.0027	0.992	38.252	412.92	0.0268	0.991	0.1718	0.994	1.6016
	50	278.599	0.0026	0.991	40.420	500.05	0.0267	0.992	0.1662	0.994	1.6260
	60	281.203	0.0024	0.991	34.637	673.53	0.0288	0.991	0.1520	0.995	1.6406
100	30	319.813	0.0031	0.991	34.366	200.22	0.0197	0.992	0.2079	0.997	1.4709
	40	326.803	0.0029	0.992	38.747	273.80	0.0202	0.991	0.1944	0.999	1.5100
	50	338.385	0.0014	0.993	39.642	267.73	0.0193	0.993	0.1973	0.998	1.5198
	60	345.496	0.0028	0.992	44.373	382.72	0.0200	0.991	0.1830	0.997	1.5588



125	30	364.906	0.0031	0.993	35.936	168.18	0.0163	0.992	0.2255	0.998	1.3953
	40	377.598	0.0032	0.992	36.366	164.50	0.0156	0.994	0.2288	0.999	1.4028
	50	391.935	0.0020	0.998	37.383	174.85	0.0152	0.991	0.2264	0.996	1.4219
	60	397.038	0.0031	0.995	42.089	228.70	0.0156	0.992	0.2129	0.997	1.4589

CONCLUSION

APPSNC prepared from *Pongamia pinnata* Shell was found to be effective in removing copper (II) ion from aqueous solution. The adsorption is faster and the rate is mainly controlled by intra-particle diffusion. Using the sorption equation obtained from the Langmuir and Freundlich isotherms, it was found that APPSNC is an effective one for the removal of copper (II) ion. The equilibrium data conformed well to the Langmuir and Freundlich isotherm models. The temperature variation study showed that the copper (II) ion adsorption is endothermic and spontaneous with increased randomness

at the solid solution interface. Significant effect on adsorption was observed on varying the pH of the copper (II) ion solution. pH dependent results and desorption of copper (II) ion in mineral acid suggest that the adsorption of copper (II) ion on APPSNC involves chemisorptions as well as physisorption mechanism.

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