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EQUILIBRIUM, KINETIC AND THERMODYNAMIC STUDY ON COPPER (II) REMOVAL FROM AQUEOUS SOLUTION USING *STRYCHNOS NUX-VOMICA* L.

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Abstract: The effective and economic removal of heavy metals from industrial effluents is one of the important issues globally. The present study proposed the use of Activated *Strychnos nux-vomica* L in the removal of Cu (II), ions from synthetic aqueous solutions. Batch adsorption experiments were carried to fix the adsorption dosage and also to find the optimum pH. Batch adsorption studies showed that Activated *Strychnos nux-vomica* L was able to adsorb Cu (II) ions from aqueous solutions in the concentration range 25–125 mg/L. The adsorption was favored with maximum adsorption at pH 6.5, whereas the adsorption starts at pH 2 for Cu (II) ions. The effects of contact time, initial concentration of Cu (II) ions, adsorbent dosage and temperature have been reported. The applicability of Langmuir and Freundlich isotherm was tried for the system to completely understand the adsorption isotherm processes. The adsorption kinetics tested with pseudo-first-order and pseudo-second-order models yielded high R^2 values fromo.850 to 0.932 and fromo.991 to 0.999, respectively. The Activated *Strychnos nux-vomica* L. was found to be cost effective and has good efficiency to remove these toxic Cu (II) ions from aqueous solution.

Key Words: Copper (II) ion, Activated *Strychnos nux-vomica* L (ASNVL), Langmuir, Freundlich isotherms and kinetics.

INTRODUCTION

Disposal of steel industry wastewater pose one of the major problems, because such effluents contain a number of contaminants including acid or base, dissolved solids, toxic compounds, and color. Out of these, color is the first contaminant to be recognized because it is visible to the human eye. Removal of Cu (II) ions by conventional waste treatment methods is difficult since these are stable to light and oxidizing agents and are resistant to aerobic digestion. Possible methods of color removal from textile effluents include chemical oxidation, froth flotation, adsorption, coagulation, etc. Among these, adsorption currently appears to offer the best potential for overall treatment, and it can be expected to be useful for a wide range of compounds, more so than any of the other listed processes. Recognizing the high cost of activated nano carbon, many investigators have studied the feasibility of cheap, commercially available materials as its possible replacements. Such materials range from industrial waste products such as waste rubber tyres[1], blast furnace slag, and lignin to agricultural products such as wool, rice straw, coconut husk, saw dust, and peat moss. Fertilizer plants generate waste slurry due to liquid fuel combustion, and this causes a disposal problem. The waste slurry is converted into a cheap carbonaceous adsorbent and used for the removal of Cu (II) ions and phenols[2]. Steel plants produce granular blast furnace slag as a byproduct, and this material also causes a disposal problem. Presently this is being used as filler. Efforts have been made to convert this waste into a potential and low-cost adsorbent.

In the present investigation the adsorption of Cu (II) ion on activated nano carbon prepared from *Strychnos nux-vomica* L Leaves by carbonization with sulphuric acid has been achieved. The kinetic and equilibrium adsorption data obtained were utilized to characterize the sample prepared[7]. The amounts and rates of adsorption of copper using above activated nano carbon from water were then measured. Three simplified kinetic models including pseudo first order, Pseudo second order equations and Elovich equations were used to describe the adsorption process.

MATERIALS AND METHODS

Chemicals

All reagents used in the experiments were of analytical (AR) grade and were obtained from Scientific Equipment Company, Trichy. Stock solutions of the test reagents were prepared by dissolving the Cu (II) ions in distilled water. 1000 mg/L of stock solution of copper (II) ($CuSO_4$, $5H_2O$) was prepared by dissolving accurately weighed 3.9296 grams 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 Cu (II) ion was determined with atomic absorption spectrophotometer (Perkin Elemer 2380).

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Preparation of adsorbent

The natural plant material *Strychnos nux-vomica* L used in the present investigations was collected from Edayappatti nearby pudukkottai district the leaves were washed with distilled water several times to remove the dirt and dust and was subsequently dried in a hot air oven at 110°C. Afterward, carbonization of the *Strychnos nux-vomica* L was carried out by w/v ratio of concentrated sulphuric acid for 1 hour, which was afterward mixed with Zinc chloride. Zinc chloride acts as a catalyst in the process. The primary carbon was activated at 1000°C for 5 hrs under optimized conditions to obtain activated nano carbon. The activated nano carbon was thereafter looked to room temperature in an insert atmosphere of nitrogen and washed with hot distilled water and 0.5 N Hydrochloric and until the pH of the material reached 7.0 the activated nano carbon was also dried in a hot air oven at 110°C, ground and sieved to obtain the desired particular size (150mm) and stored in desiccators for further use.

Batch Adsorption studies

Preliminary batch adsorption studies were conducted to determine the equilibrium time. Batch studies were performed by mixing 0.025g of Cu (II) ion with some of solution of different initial concentrations of Cu (II) ion in 250 ml stoppered conical flask. The dose of adsorbent was decided experimentally. All the adsorption experiments were conducted at 30° to 60°C, at an agitation speed of 150 rpm on the thermostat sharing water bath, the progress of adsorption was noted and equilibrium was achieved in 50 min. After equilibrium, the adsorbent was separated from the age use phase by centrifugation at 1000 rpm for to min using a centrifuge (Remi 24, India). The residual concentration of Cu (II) ions in the supernatant was determined by a UV–Visible spectrophotometer at 618nm. The percentage removal of Cu (II) ions at equilibrium and the amount of Cu (II) ions transferred onto the surface of the adsorbent, q_e (mg/g) was calculated using the following relationships.

$$\text{Percentage metal removal} = 100\,(Co\text{-}Ce)/Co \qquad (1)$$

Amount of adsorbed Cu (II) ions molecules per g of solid

$$Qe = (Co\text{-}Ce)\ v/w \qquad (2)$$

Where, C_o (mg/L) is the initial concentration of Cu (II) ion, C_e (mg/L) is the equilibrium concentration of Cu (II) ions, V is the volume of the solution (L), and w (g) is the mass of the adsorbent.

RESULT AND DISCUSSION

Characterization of Adsorbent

Effect of operating variables on the adsorption of Cu (II) ions onto Activated *Strychnos nux-vomica* L the adsorbent of materials, ASNVL were used to absorb some mg of Cu (II) ion respectively.

Strychnos nux-vomica L.

The adsorption capacity of ASNVL is better than other, with the increase amount of ASNVL the removal of Cu (II) increased obviously.

Table 1: Characteristics of the Adsorbent

Properties	ASNVL
Particle size(mm)	0.0150
Density (g/cc)	0.2005
Moisture content (%)	0.2527
Loss in ignition (%)	0.0110
pH of aqueous solution	6.5000

Effect it contact time

Figure 1 illustrates the effects of contact time on the removal of Cu (II) ion respectively for different initial Cu (II) ions concentrations; the changes in contact time exhibit approximately the same effects on the Cu (II) ion. Because of the utilization of the readily available active adsorption sites on the as surface[3], the adsorption of Cu (II) ions was rapid for the first 30 min for all the investigated initial Cu (II) ions concentrations. There after it continued at a slower rate and finally reached equilibrium as a result of saturation it as surface sites, for all three Cu (II) ions, at all of the storied initial Cu (II) ions concentrations a sufficient contact time was determined as 30 min.

Table 2: Equilibrium Parameters for the Adsorption of Cu (II) ion onto ASNVL

M_o	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	2.6412	2.6541	2.5435	2.5275	44.702	44.682	44.902	44.956	89.414	89.373	89.814	89.916
50	5.4456	5.8453	5.4620	4.8741	89.103	88.316	89.061	90.253	89.107	88.316	89.063	90.253
75	13.834	12.891	11.845	10.653	122.34	124.20	126.38	128.61	81.555	82.804	84.201	85.794
100	26.743	25.647	11.848	28.446	146.56	148.75	176.37	143.15	73.259	74.352	88.155	71.552
125	45.848	40.336	23.843	32.989	158.31	169.33	202.36	184.01	63.326	67.728	80.922	73.612

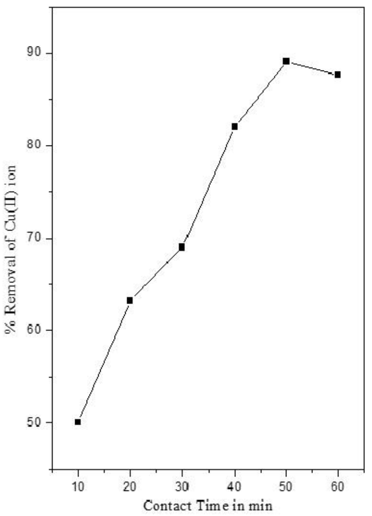

Figure 1: Effect of contact time on the removal of Cu (II) ion
[Cu] = 50mg/L; Temperature 30°C

Effect of adsorbent concentration

ASNVL with different concentrations were combined with a fixed 50ml, 50 mg/L of Cu (II) ion respectively the adsorption of Cu (II) ions increased with the increase of absorbent dose, and reached to a plateau at the appropriate dose of 125 mg of ASNVL. The results were shown in the fig. 2.

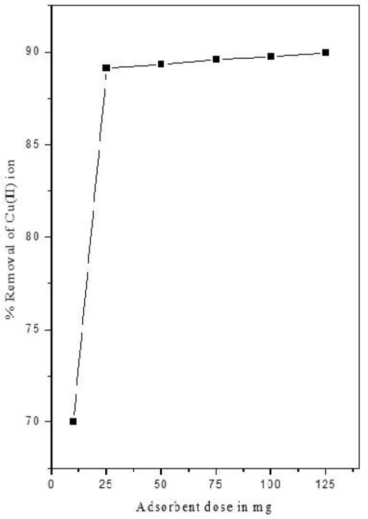

Figure 2: Effect of adsorbent dose on the removal of Cu (II) ion
[Cu] = 50mg/L; Contact time = 50min; Temperature 30°C

Effect of intoned pH on adsorption

The pH value of the solution was important controlling parameters in the adsorption process, the removal of Cu (II) ions increase significantly with increasing pH from 1 to 7. The removal efficiencies of Cu (II) ions were low at pH<4. The obvious decreasing of removal might be attributed to the repulsive forces between the positive surface charge of adsorbate and the positive Cu (II) ions[4]. The result shows that the fig 3.

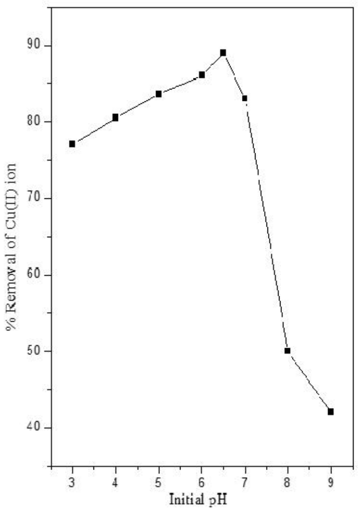

Figure 3: Effect of Initial pH on the removal of Cu (II) ion
[Cu] = 50mg/L; Contact time = 60min; Adsorbent dose = 25mg/50ml

pH optimization

The removal of Cu (II) at different pH was studied in batch mode. A 50 ml of test solution of fixed concentrations was treated with 0.025 g of ASNVL and agitated intermittently for 60 min. The contact time and conditions were selected on the basis of preliminary experiments, which demonstrated that equilibrium was established in 60 min. After this period the solutions then both phases were separated by filtration. The Cu (II) ion content of the filtrate was determined by atomic spectrometry. The Cu (II) ions concentration retained in the sorbent phase (q_e, mg/g) was calculated by using Eq. (1)

$$q_e = \frac{(C_0 - C_e)\,V}{m} \qquad (3)$$

Where, C_0 and C_e are the initial and final (equilibrium) concentrations of the Cu (II) ion in solution (M), V the solution volume (L) and m is the mass of Activated *Strychnos nux-vomica* L (g).

Adsorption Kinetic and isotherm models

Adsorption Isotherms: Adsorption isotherms describe the interaction of adsorbate with adsorbents. The experimental adsorption data of Cu (II) ions on the Activated *Strychnos nux-vomica* L were analyzed by Langmuir and Freundlich isotherms.

Langmuir Isotherm: The Langmuir adsorption model is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface, with no lateral interaction between the adsorbed molecules. The Langmuir adsorption isotherm has been successfully used in many monolayer adsorption processes, the values are in table 3. The adsorption isotherm data were analyzed by the Langmuir isotherm model in the linearized form.

Table 3: Langmuir and Freundlich Isotherm Parameter for the Adsorption of Cu (II) ion onto ASNVL

Temp. (°C)	**Langmuir Parameters**		**Freundlich Parameters**	
	Q_m	b	**K_f**	**n**
30°C	183.02	0.1444	4.7452	2.3763
40°C	204.13	0.1154	4.5714	2.1330
50°C	340.96	0.0626	4.1089	1.4633
60°C	205.77	0.1316	4.7424	2.1604

Table 4: Dimensionless Separation Factor (R_L) for the Adsorption of Cu (II) ion onto ASNVL

(C_i)	**Temperature °C**			
	30°C	**40°C**	**50°C**	**60°C**
25	0.2168	0.2572	0.3896	0.2330
50	0.1216	0.1476	0.2419	0.1318
75	0.0845	0.1034	0.1754	0.0919
100	0.0647	0.0796	0.1376	0.0706
125	0.0524	0.0647	0.1132	0.0572

$$C_e/q_e = C_e/q_{max} + 1/(b\ q_{max}) \qquad (4)$$

Where, q_e is the equilibrium adsorption capacity of the adsorbent (mg/g), C_e is the equilibrium Cu (II) ion concentration in solution (mg/l), q_{max} is the maximum amount of Cu (II) ion that could be adsorbed on the adsorbent (mg/g) and b is the Langmuir adsorption equilibrium constant (L/mg). 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 by the equation

$$R_L = (1/(1+bC_o)) \qquad (5)$$

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 4. The values of b were increased with increasing the dose of adsorbent for ASNVL High b values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 205 mg/L for ASNVL.

Freundlich Isotherm

The Freundlich model can be applied to multilayer adsorption with non-uniform distribution of adsorption heat and affinities over the heterogeneous surface[12]. The experimental data were analyzed by Freundlich isotherm model in the linearized form,

$$\log q_e = 1/n \log C_e + \log K_F \qquad (6)$$

Where, K_F is the Freundlich adsorption constant and it is the maximum adsorption capacity of Cu (II) ions (mg/g) and n is the constant illustrates the adsorption intensity (dimensionless). The values tabulated in table 3 shows the favorability of adsorption.

Kinetic studies

The Kinetic adsorption data were evaluated to understand the dynamics of the adsorption reaction in terms of the order of the rate constant batch experiments were conducted to explore the rate of Cu (II) ion adsorption by Activated *Strychnos nux-vomica* L as described in adsorption isotherms section at pH 7. Three Kinetic models were applied to the adsorption Kinetic data in order to investigate the behavior of adsorption process of Cu (II) ion onto the adsorbents. These models include the pseudo first order Kinetics (reversible or irreversible), the pseudo – Second – order and the intra particle diffusion models the linear form of reversible pseudo – first – order model can be formulated as:

$$\ln\left(q_e - q_t\right) = \ln q_e - k_1 x\ t \qquad (7)$$

Where, q_e (mol/g) and q_t (mole/g) are the amount of Cu (II) ion adsorbed at equilibrium and at time t, respectively and K_1 (min-1) is the rate constant K_1 values were evaluated from the linear regression of ln (q_e-q_t) versus data. Linear from of irreversible pseudo first order model can be formulated as:

$$\ln\left(C_o / C_t\right) = K \times t \qquad (8)$$

Where, C_o (mg/l) is the initial concentration of Cu (II) ion and C_t (mg/l) is equilibrium concentration of Cu (II) ion at time t respectively, and Kg min^{-1} is the rate constant evaluation of data has been done using linear plot of ln (C_o/C_t) versus time. The Linear form of pseudo -Second-order equation can be formulated us.

$$t/q_t = 1/K_2 q_e^2 + t/q_e \qquad (9)$$

Where, q_e and q_t are surface loading of Cu (II) ion at equilibrium and time t respectively and K_2 (g/mg/min) is the second-order rate constant, The Linear plot of t/q_t as a function of provided not only the rate constant k_2, but also an independent evaluation of q_e. The fitting of experimental data to the pseudo – first – order and the pseudo – second- order equation seemed to be quite good for ac where the calculated correlation coefficient s (R^2) almost the same values

For adsorption of Cu (II) ion on to Activated *Strychnos nux-vomica* L the obtained results represent more conformity to pseudo-second order model (R^2 =0.95), the initial adsorption rate $k_2q_e^2$ for Activated *Strychnos nux-vomica* L (0.028mg/min).

The Elovich equation and intra-particle diffusion model

The Elovich model equation is generally expressed as

$$dq_t / d_t = \alpha \exp(-\beta q_t) \qquad (10)$$

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 $\alpha\beta t >> t$ and by applying boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ Eq.(10) becomes:

$$q_t = 1/\beta \ln(\alpha\beta) + 1/\beta \ln t \qquad (11)$$

Since, 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 6. 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 ASNVL adsorbent.

Table 6: The Kinetic Parameters for the Adsorption of Cu (II) ion onto ASNVL

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**	48.572	0.0022	0.9952	8.6221	94.656	0.1503	0.9959	1.6558	0.994	0.1684
	40	47.203	0.0018	0.9983	12.083	138.53	0.2206	0.9968	1.7524	0.995	0.1099
	50	47.308	0.0017	0.9960	12.1445	297.07	0.2401	0.9982	1.7762	0.997	0.0998
	60	49.046	0.0022	0.9940	8.1721	113.84	0.1555	0.9948	1.6673	0.999	0.1602
50	**30**	98.084	0.0024	0.9946	13.456	140.44	0.0734	0.9961	1.6330	0.998	0.1737
	40	94.223	0.0020	0.9988	19.134	151.25	0.1054	0.9987	1.7341	0.997	0.1170
	50	94.065	0.0018	0.9954	23.156	334.82	0.1137	0.9967	1.7556	0.998	0.1068
	60	95.872	0.0018	0.9990	22.275	152.48	0.1017	0.9989	1.7427	0.992	0.1187
75	**30**	131.375	0.0022	0.9987	25.091	113.74	0.0701	0.9984	1.6795	0.994	0.1277
	40	133.187	0.0022	0.9967	26.045	130.56	0.0702	0.9967	1.6834	0.991	0.1255
	50	134.93	0.0021	0.9961	27.662	198.35	0.0727	0.9983	1.7061	0.992	0.1186
	60	137.89	0.0021	0.9981	27.712	144.82	0.0682	0.9943	1.7037	0.991	0.1245
100	**30**	159.42	0.0025	0.9975	24.541	479.35	0.0507	0.9982	1.5842	0.992	0.1502
	40	160.43	0.0023	0.9969	28.726	939.64	0.0547	0.9972	1.6291	0.991	0.1354
	50	164.56	0.0011	0.9973	31.182	106.68	0.0537	0.9969	1.6428	0.993	0.1337
	60	149.49	0.0013	0.9989	76.546	163.93	0.0938	0.9981	1.7263	0.991	0.0773
125	**30**	175.67	0.0025	0.9928	23.325	406.02	0.0451	0.9948	1.5126	0.992	0.1555
	40	184.03	0.0024	0.9941	30.036	526.66	0.0431	0.9994	1.5553	0.994	0.1530
	50	191.94	0.0015	0.9948	31.246	625.97	0.0423	0.9972	1.5742	0.991	0.1490
	60	199.22	0.0024	0.9959	33.362	892.22	0.0427	0.9963	1.6051	0.992	0.1408

For adsorption of Cu (II) ion on to Activated *Strychnos nux-vomica* L the obtained results represent more conformity to pseudo-second order model (R^2 =0.95), the initial adsorption rate $k_2 q_e^2$ for Activated *Strychnos nux-vomica* L. Kinetic data for the adsorption of Cu (II) ion were also analyzed according to intra-particle diffusion model achieve can be formulated as.

$$Qt = k_p t^{0.5} \qquad (12)$$

Where, q_t is the amount of Cu (II) ion adsorbed (mg/g) at time t, and k_p (mg/g $min^{0.5}$) is the rate constant for intra – particle diffusion. Results are shown in table 6. Usually the plot of qt versus $t^{0.5}$ may be distinguished in two or more steps taking place during adsorption process including instantaneous adsorption stage by external mass transfer (first sharper portion), intra-particle diffusion which is the rate controlling stage (second portion as the gradual adsorption stage) and the final equilibration of age Where, the intra – particle diffusion starts to slow down due to extremely low solute concentration in solution (the third portion).

Adsorption Thermodynamics

The thermodynamic parameters for the adsorption of Cu (II) ions by Activated *Strychnos nux-vomica* L were determined using the following equations:

$$K_D = q_e/C_e \qquad (13)$$

$$\Delta G^\circ = -RT \ln K_D \qquad (14)$$

$$\ln K_D = (\Delta S^\circ/R) - (\Delta H^\circ/RT) \qquad (15)$$

Where, K_D is the distribution coefficient for the adsorption in g/L, ΔG° is the Gibbs free energy in J/mol,

R is the universal gas constant in J/mol K, T is the absolute temperature in K, ΔS° is the entropy change in J/mol K and ΔH° is the enthalpy change in kJ/mol[13]. The values of Gibbs free energy (ΔG°) for various temperatures were calculated from the experimental data. The values of enthalpy change (ΔH°) and entropy change (ΔS°) were estimated from the slope and intercept of the plot of ln K_D Vs 1/T. The estimated thermodynamic parameters were tabulated and shown in table 5. The negative values of Gibbs free energy change (ΔG°) obtained for the adsorption of Cu

(II) ions by Activated *Strychnos nux-vomica* L at various temperatures had shown the spontaneous nature of the adsorption process.

Table 5: Thermodynamic Parameter for the Adsorption of Cu (II) ion onto ASNVL

(C_0)	**ΔG°**				**ΔH°**	**ΔS°**
	30°C	**40°C**	**50°C**	**60°C**		
25	-5376.67	-5541.3	-5845.4	-6057.41	1.7360	23.40
50	-5292.81	-5262.43	-5631.9	-6161.48	3.6496	29.046
75	-3744.83	-4090.38	-4494.8	-4979.05	8.6780	40.896
100	-2538.41	-2770.39	-5390.4	-2554.5	6.3538	30.402
125	-1375.76	-1929.25	-3880.9	-2840.56	18.286	65.387

The positive values of enthalpy change (ΔH°) obtained for the adsorption of Cu (II) ions by Activated *Strychnos nux-vomica* L at various temperatures indicated that the adsorption reactions were endothermic. The positive values of entropy change (ΔS°) for the adsorption of Cu (II) ions by Activated *Strychnos nux-vomica* L at various temperatures showed the increased randomness at solid liquid interphase during the sorption processes of Cu (II) ions on the adsorbent ASNVL. This is a direct consequence of (i) opening up of structure of adsorbent beads (ii) enhancing the mobility and extent of penetration within the adsorbent beads and (iii) overcoming the activation energy barrier and enhancing the rate of intra-particle diffusion[14].

The adsorption of Cu (II) ions by Activated *Strychnos nux-vomica* L slightly increased when temperature was raised up to 60°C. It might be due to the generation of new active sites on the adsorbent surface and also due to the increased rate of pore diffusion. It showed that the adsorption processes of Cu (II) ions by Activated *Strychnos nux-vomica* L were endothermic reactions and physical in nature which involved the weak forces of attraction between the sorbate-sorbent molecules.

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the Cu (II) ions. If the adsorbed Cu (II) ions can be desorbed using neutral pH water, then the attachment of the Cu (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 Cu (II) ion. The reversibility of adsorbed Cu (II) ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of Cu (II) ion by mineral acids and alkaline medium indicates that the Cu (II) ion was adsorbed onto the ASNVL through physisorption as well as by chemisorptions mechanisms[20].

CONCLUSION

The adsorption of Cu (II) ions on the adsorbent was found to be initially concentration- and temperature dependent, and followed both the Freundlich and Langmuir isothermal adsorption. Moreover, R_L, a dimensionless separation factor of an equilibrium parameter, was far less than 0.1 indicating the favorable adsorption. The concentration helped to increase the equilibrium adsorption capacity, and higher temperature favored the adsorption. The positives values for ΔH° indicated that the process was endothermic. The positive values of entropy ΔS° suggested some structural changes in the adsorbate and adsorbent,

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REFERENCES

1. Ajamal H, Mohammad A, Anwar S. Sorption studies of heavy metals on teak leaves using thin layer and column chromatographic technique, Pollut Res, 2001, (3), 425 – 428.

2. Anbalagan K, Juliet JC, Adsorption of Cr (VI) ion onto activated amla dust: Adsorption isotherms and kinetics, Indian J Chem Technol, 2004, 43, A: 45:50.

3. Brown P, Jefcoat I, Parrish A, Dana G, Sarah S, Graham E, Evaluation of the adsorptive capacity of peanut hull pellets for heavy metals in solution, Adv Environ Res, 2000, 4(1), 19-29.

4. Chien SH, Clayton WR, Application of Elovich Equation to the kinetics of Phosphate release and sorption on soil, Soil Sci Sco Am J, 1980, 44, 265 – 268.

5. Arivoli S, Marimuthu V, Rose Judith T, Equilibrium and Thermodynamics Studies on the Removal of Iron (III) onto Activated Pistia Stratiotes Leaves Nano Carbon, Res Rev J of Chem, 2014, 3(1), 15-22.

6. Jambulingam M, Rehugadevi N, Karthikeyan S, Kiruthika J, Patabhi S, Adsorption of Cr(VI) from aqueous solution using a low cost activated nano carbon, Indian J Environ Protect, 2005, 25(5), 458-63.

7. Mohanty K, Jha M, Biswas, MN, Meikap BC, Removal of chromium (VI) from dilute aqueous solutions by activated nano carbon developed

from Terminalia arjuna nuts activated with zinc chloride, Chem Engg Sc, 2005, 60(11), 3049-3059.

8. Namasivayam C, Holl WH, Chromium (III) removal in tannery wastewaters using Chinese reed (Miscanthus Sinensis), a fast growing plant, Holz Roh Werkst, 2004, 62, 74 – 80.

9. Nikhel K, Ecological management of polluted waters due to mining and allied industries, J Indust Pollut Contamin, 2005, 12(2), 225-271.

10. Arivoli S, Marimuthu V, Rose Judith T, Kinetic, Equilibrium and Mechanistic Studies of Nickel Adsorption on Activated Pistia stratiotes Leaves, Euro J of App Sci &Tech, 2014, 1(1), 15-22.

11. Rao M, Bhole AG, Chromium removal by adsorption using fly ash and bagasse, J Indian Water Works Assoc, 2004, 97, 997 – 1000.

12. Rao M, Bhole AG, Chromium removal by adsorption using fly ash and bagasse, J Indian Water Works Assoc, 2001, 97, 997 – 1000.

13. Sharma A, Bhattacharya D, Utilisation of biosorbent based on Azadirachta indica (Neem) leaves for removal of water soluble Metals, Indian J Environ Chem, 2005, 12, 285-295.

14. Sharma YC, Adsorption of Cr (VI) onto wallastonite: Effect of pH, Indian J Chem Technol, 2001, 8, 191 – 194.

15. Shiny KJ, Remani KN, Jalaja TK, Sasidharan VK, Removal of chromium by two aquatic Pteridophytes, Indian J Environ Health, 2004, 46, 249–251.

16. Shrivastava RK, Ayachi AK, Mora M, Removal of Cr (VI) by utilization of Bidi leaves, Pollut Res, 2001, 20(4), 639 – 643).

17. Singh IB, Singh DR, Hexavalent chromium removal using iron bearing industrial sludge's, Indian J Chem Technol, 2001, 8, 487-495.

18. Volesky B, Sorption and Bi-sorption, Montreal-St, Lambert, Quebec, Canada, BV Sorbex Inc., 2003, 316p.

19. Weber WJ, Morris JC, Kinetics of adsorption on Carbon from solution, J Sanitary Engg Div, 1964, 90, 79.

20. Wittbrodt, PR, Palmer CD, Reduction of Cu (II) in the presence of excess soil fulvic acid. Environ. Sci. and Technol, 1995, 29: 255 – 265.

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