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Removal of copper ion from effluent by low cost activated carbon

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Abstract

The activated carbon was prepared using solid waste called *Terminalia Catappa Linn* shell and the physicochemical properties of carbon were investigated to explore the adsorption process. The effectiveness of such carbon in adsorbing copper ion from aqueous solution has been studied as a function of agitation time, adsorbent dosage, initial metal ion concentration, temperature, pH, and desorption. Adsorption equilibrium studies were carried out in order to optimize the experimental conditions. The adsorption of copper ion onto carbon followed a first order kinetic model. Adsorption data were modeled using both Langmuir and Freundlich classical adsorption isotherms. The adsorption capacity $Qm$was 30.60, 33.85, 35.87, and 38.35 at initial pH 7.0. The equilibrium time was found to be 40 min for all initial concentrations studied. Desorption studies were performed with dilute HCl and show that ion exchange is the predominant copper ion adsorption mechanism. The adsorbent was found to be both effective and economically viable.

Keywords: Activated carbon (TCC), copper ion, adsorption isotherm, equilibrium, kinetic and thermodynamic parameters, intraparticle diffusion, regeneration pattern.

1.Introduction

Rapid industrialization and urbanization has resulted in the deterioration of water, air, and land quality. Natural waters are contaminated with various heavy metals arising from mining wastes and industrial discharges. The tremendous increase in the use of heavy metals over the past few decades has resulted in an increased flux of metallic substances into the environment. The heavy metals are of special concern because they are non-degradable and therefore persistent. Commonly encountered metals of concern include Pb, Cu, Zn, Co, Ni ions etc. These metals are toxic both in their chemically combined forms and in the elemental form. Exposure to these contaminants, even in low concentrations in the environment, can prove to be harmful to human health. In order to solve heavy metal pollution in the environment, it is important to bring applicable solutions. Some in-place treatment technologies available for the removal of heavy metal ions from aqueous solutions are chemical precipitation, ion exchange, coagulation, and bioremediation and sorption/ adsorption. Of all these techniques adsorption at solid substrate is preferred because of its high efficiency, easy handling, and cost effectiveness as well as the availability of different adsorbents [1, 5]. The present study is undertaken to evaluate the efficiency of a carbon adsorbent prepared from acid activated Terminalia Catappa Linn shell carbon for the removal of copper ion aqueous solution, since it carries a large surface area and active sites to adsorb the metal ion under study. In order to design adsorption treatment systems, knowledge of kinetic and mass transfer process is essential. In this paper, we have reported the applicability of kinetic and mass-transfer models for the adsorption of copper ion onto activated carbon.

2. Materials and Methods

2.1. Adsorbent

Carbon was prepared by treating air-dried *Terminalia Catappa Linn* shell with conc. sulfuric acid at a weight ratio of 1:1. The resulting black product was kept in a furnace maintained at 400 °C for 12 hours, followed by washing with water until free from excess acid, and then dried at 150 ± 5 °C. The carbon product obtained was ground and the portion retained between 0.040 to 0.045 mm sieves was used in all the experiments. All chemicals were supplied by S.D. fine chemicals with high purity.

2.2. Batch Equilibration Method

All experiments were carried out at 30, 40, 50, and 60ºC temperature in batch mode. Batch mode was selected because of its simplicity and reliability. The experiments were done in different Erlenmeyer glass flasks of 100 ml capacity. Prior to each experiment, a predetermined amount of absorbent was added to each flask. The stirring was kept constant (120 rpm) for each run throughout the experiment to ensure equal mixing. Each flask was filled with a known volume of sample before commencing stirring, such as metal solutions with an initial concentration of 10 mg/l to 50 mg/l. The flask containing the sample was withdrawn from the shaker at the predetermined time interval, filtered and the residual concentration of the metal ion was measured.

2.3. Effect of Variable Parameters

2.3.1. Dosage of Adsorbents

Different doses consisting of 10 to 250 mg/50 ml of the adsorbent is mixed with the copper ion and the mixture was agitated in a mechanical shaker. The percentage of adsorption for different doses was determined by keeping all other factors constant.

2.3.2. Initial Concentration

In order to determine the rate of adsorption, experiments were conducted with different initial concentrations of copper ions ranging from 10 to 50 mg/l. All other factors were kept constant.

2.3.3. Contact Time

The effect of period of contact between the adsorbent and adsorbate on the removal of the copper ions in a single cycle was determined by keeping particle size, initial concentration, dosage, pH, and temperature constant.

2.3.4. Initial pH

Adsorption experiments were carried out at a range of pH of the solution, *i.e.* 3–10. The acidic and alkaline pH of the medium was maintained by adding the required amounts of hydrochloric acid and sodium hydroxide solutions. Parameters such as particle size of the adsorbents and temperature were kept constant while carrying out the experiments.

2.3.5. Other Ions

Adsorption studies of a specific metal ion in the presence of chloride, nitrate, and calcium ions were experimentally verified using the adsorbents. This involved the determination of the percentage of metal ion adsorbed from 30 mg/l of initial concentration of the metal ion solution with varying concentration of the added ion, keeping all other factors constant.

2.3.6. Temperature

The adsorption experiments were performed at four different temperatures, viz., 30, 40, 50, and 60 ºC, in a thermostatted shaker machine (Remi, India). The temperature was maintained constant with an accuracy of ± 0.5 ºC.

2.3.7. Zero Point Charge

The pH at the potential of zero charge of the carbon (pHzpc) was measured using the pH drift method. The pH of the solution was adjusted by using 0.01 M sodium hydroxide or hydrochloric acid. Nitrogen was bubbled through the solution at 25 ºC to remove the dissolved carbon dioxide. 50 mg of the activated carbon was added to 50 ml of the solution. After stabilization, the final pH was recorded. The graphs of final pH versus initial pH used to determine the zero point charge of the activated carbon [6].

2.4. Titration Studies

According to Boehm, [6] only strong acidic carboxylic acid groups are neutralized by sodium bicarbonate, whereas those neutralized by sodium carbonate are thought to be lactones, lactol, and carboxyl group. The weakly acidic phenolic groups only react with strong alkali (sodium hydroxide). Therefore, by selective neutralization using bases of different strength, the surface acidic functional group in carbon can be characterized both quantitatively and qualitatively. Neutralization with hydrochloric acid characterizes the amount of surface basic groups that are, for example, pyrones and chromenes. The basic properties have been ascribed to surface basic groups and the π electron system of carbon basal planes. The results indicate that the activated carbon used may possesses acidic oxygen functional groups on their surface and this is well supported by their respective zero point charge values. The results obtained from the above characterization studies are given in Table 1.

2.5. Regeneration Studies

The regeneration of the adsorbed carbon is done by using 0.2 M mineral acids and sodium chloride solutions.

3. Results and Discussion

3.1. Characterization of the Adsorbent

Activated carbons are widely used as adsorbents due to their high adsorption capacity, high surface area, microporous structure, and high degree of surface. The wide usefulness of carbons is a result of their specific surface area, and 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.

3.2. Effect of Contact Time and Initial Copper Ion Concentration

The experimental results for adsorptions of copper ion on the activated carbon at various concentrations (10, 20, 30, 40, and 50 mg/l) and contact times are shown in Figure 1. The equilibrium data, collected in Table 2, reveals that percent adsorption decreased with increase in initial copper ion concentration, but the actual amount of copper ion adsorbed per unit mass of carbon increased with increase in metal ion concentration. This means that the adsorption is highly dependent on the initial concentration of copper ion. This is because at lower concentration, the ratio of the initial number of copper ion to the available surface area is low; subsequently the fractional adsorption becomes independent of initial concentration. However, at high concentration the available sites of adsorption becomes fewer, and hence the percentage removal of copper ion is dependent upon initial concentration. Equilibrium was established at 40 minutes for all concentrations. Figure 1 reveals that the curves are single, smooth, and continuous.

Table 1. Characteristics of the Adsorbent

Properties	TCC
Particle size (mm)	0.045
Density (g/cc)	0.3258
Moisture content (%)	1.85
Loss on ignition (%)	82
Acid insoluble matter (%)	3
Water soluble matter (%)	0.78
pH of aqueous solution	7.00
pH_{zpc}	6.15
Surface groups (m equiv/g)	
(*i*) Carboxylic acid	0.323
(*ii*) Lactone, lactol	0.065
(*iii*) Phenolic	0.058
(*iv*) Basic (pyrones and chromenes)	0.032

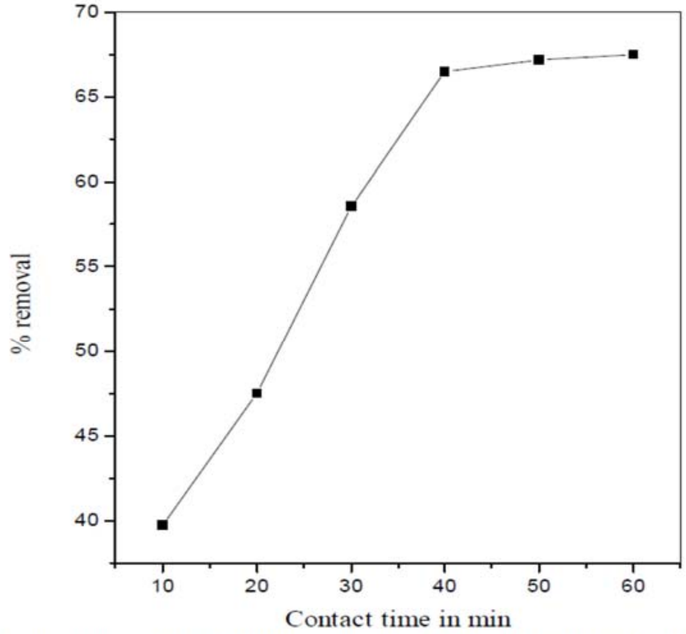


Figure 1. Effect of contact time on the adsorption of copper ion [Cu] = 30 mg/l; Adsorbent dose = 50 mg/50 ml

Table 2. Equilibrium Parameters for the Adsorption Copper Ion Onto PCC

Copper ion	C_e (mg /l)				Q_e (mg/g)				Metal ions removed (%)			
	30°	40°	50°	60°	30°	40°	50°	60°	30°	40°	50°	60°
10	2.1575	1.9032	1.6135	1.3245	7.8425	8.0968	8.3865	8.6755	78.42	70.96	85.47	87.37
20	5.3272	4.8435	4.5245	4.0154	14.6720	15.1565	15.4755	15.9846	73.36	75.78	77.37	79.92
30	9.9732	8.8835	7.7435	6.9898	20.0268	21.1165	22.2565	23.0102	66.75	70.38	74.18	76.70
40	18.5742	17.0685	15.5835	14.0013	21.4258	22.9315	24.4165	25.9987	53.56	57.32	61.04	64.99
50	24.5347	22.4935	20.5114	18.4932	25.4653	27.8065	29.4886	31.5083	50.93	55.01	58.97	63.01

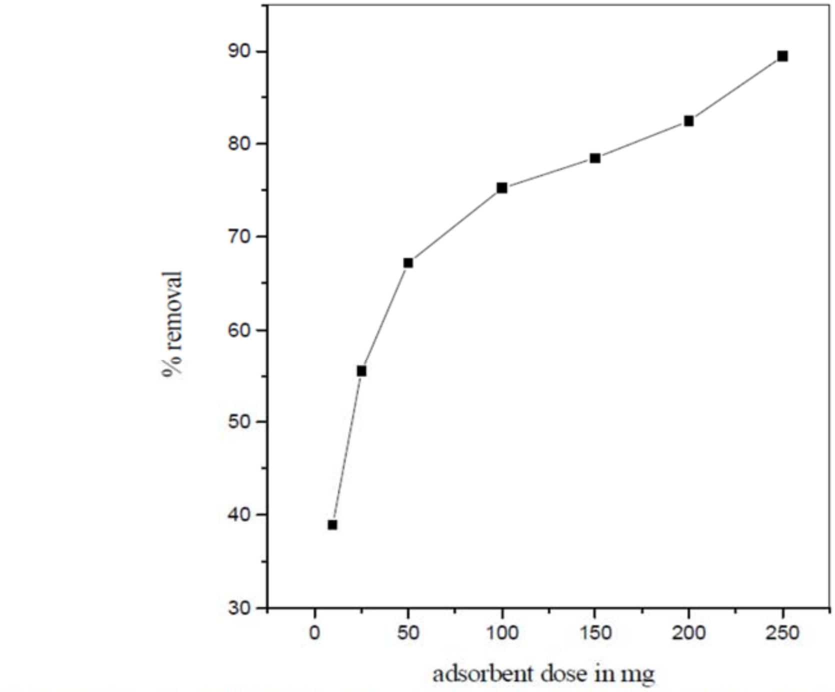


Figure 2. Effect of adsorbent dose on the adsorption of copper ion [Cu] = 30 mg/l; Contact time = 60 min

3.3. Effect of Carbon Concentration

The adsorption of the copper ion on carbon was studied by varying the carbon concentration (10–250mg/50ml) for copper ion concentration of 30mg/l. The percentage of adsorption increased with increase in the carbon concentration (Figure 2). This was attributed to increased carbon surface area and the availability of more adsorption sites [7, 8].

3.4. Adsorption Isotherm

The experimental data was analyzed according to the linear form of the Langmuir [9] and Freundlich [10] isotherms.

The Langmuir isotherm is represented by the following equation

$$Ce/Qe = 1/Qmb + Ce/Qm (1)$$

where$Ce$is the equilibrium concentration (mg/l), $Qe$is the amount adsorbed at equilibrium (mg /g), and $Qm$and b are Langmuir constants related to adsorption efficiency and energy of adsorption, respectively. The linear plots of Ce/Qe versus Cesuggest the applicability of the Langmuir isotherms. Values of $Qm$and b were determined from the slope and intercepts of the plots and are presented in Table 3. From the results, it is clear that the value of adsorption efficiency $Qm$and adsorption energy b of the carbon increases on increasing the temperature. From the values, we can conclude that the maximum adsorption corresponds to a saturated monolayer of adsorbate molecules on the adsorbent surface with constant energy and no transmission of adsorbate in the plane of the adsorbent surface [11, 12]. The trend shows that the adsorbent prefers to bind to acidic ions and that speciation predominates on the sorbent characteristics, when ion exchange is the predominant mechanism. Further, this confirms the endothermic nature of the processes involved in the system. To confirm the favorability of the adsorption process, the separation factor (RL) has calculated and presented in Table 4. The values were found to be between 0 and 1 and confirm that the ongoing adsorption process is favorable [12, 13].

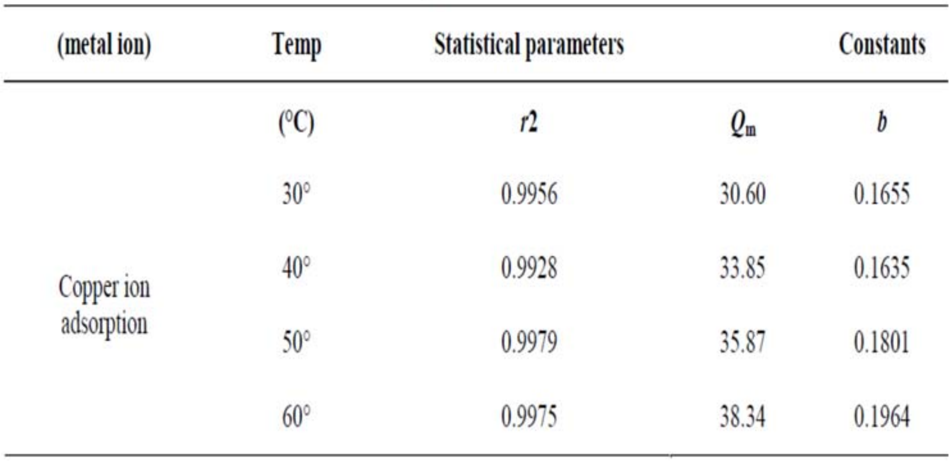
The Freundlich equation has also been employed for the adsorption of copper ion on the adsorbent. The Freundlich isotherm was represented as

$$\log Qe = \log Kf + 1/n \log Ce (2)$$

where$Qe$is the amount of copper ion adsorbed (mg/ g), $Ce$is the equilibrium concentration of metal ion in solution (mg/l), and $Kf$and n are constants incorporating all factors affecting the adsorption capacity and intensity of adsorption, respectively. The linear plot of log Qeversus log Ceshows that the adsorption of copper ion follows the Freundlich isotherm. Values of $Kf$and n were found and are given in Table 5, showing the increase of negative charge on the surface that enhances the electrostatic force such as Vanderwaal's between the carbon surface and metal ion, which increases the adsorption of copper ion. The values clearly show that dominance in adsorption

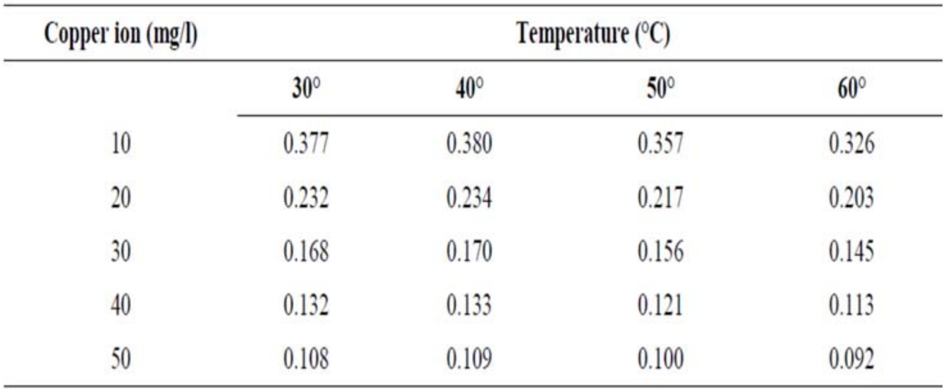
capacity. The intensity of adsorption is an indicative of the bond energies between copper ion and adsorbent and the possibility of slight chemisorptions rather than physisorption [11, 14]. The possibility of multilayer adsorption of metal ion through the percolation process cannot be ruled out. However, the value of n is greater than one, indicating the adsorption is much more favorable [14, 15].

Table 3. Langmuir Isotherm Results



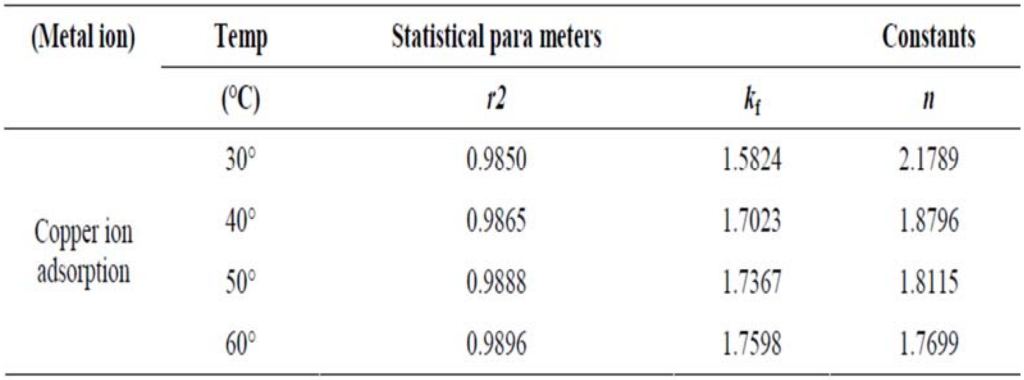
(metal ion)	Temp	Statistical parameters		Constants
	(°C)	r2	Q_m	b
Copper ion adsorption	30°	0.9956	30.60	0.1655
	40°	0.9928	33.85	0.1635
	50°	0.9979	35.87	0.1801
	60°	0.9975	38.34	0.1964

Table 4. Dimensionless Separation Factor (R_L)



Copper ion (mg/l)	Temperature (°C)			
	30°	40°	50°	60°
10	0.377	0.380	0.357	0.326
20	0.232	0.234	0.217	0.203
30	0.168	0.170	0.156	0.145
40	0.132	0.133	0.121	0.113
50	0.108	0.109	0.100	0.092

Table 5. Freundlich Isotherm Results



(Metal ion)	Temp	Statistical para meters		Constants
	(°C)	r2	k_f	n
Copper ion adsorption	30°	0.9850	1.5824	2.1789
	40°	0.9865	1.7023	1.8796
	50°	0.9888	1.7367	1.8115
	60°	0.9896	1.7598	1.7699

3.5. Kinetics of Adsorption

Kinetics of sorption describes the solute uptake rate, which in turn governs the residence time of sorption reaction. It is one of the important characteristics in defining the efficiency of sorption. In the present study, the kinetics of the copper ion removal has carried out to understand the behavior of this low-cost carbon adsorbent. The adsorption of copper ion from an aqueous solution follows reversible first-order kinetics, when a single species is considered on a heterogeneous surface. The heterogeneous equilibrium between the copper ion solution and the activated carbon was expressed as

$$A \underset{k_2}{\overset{k_1}{\rightleftarrows}} B$$

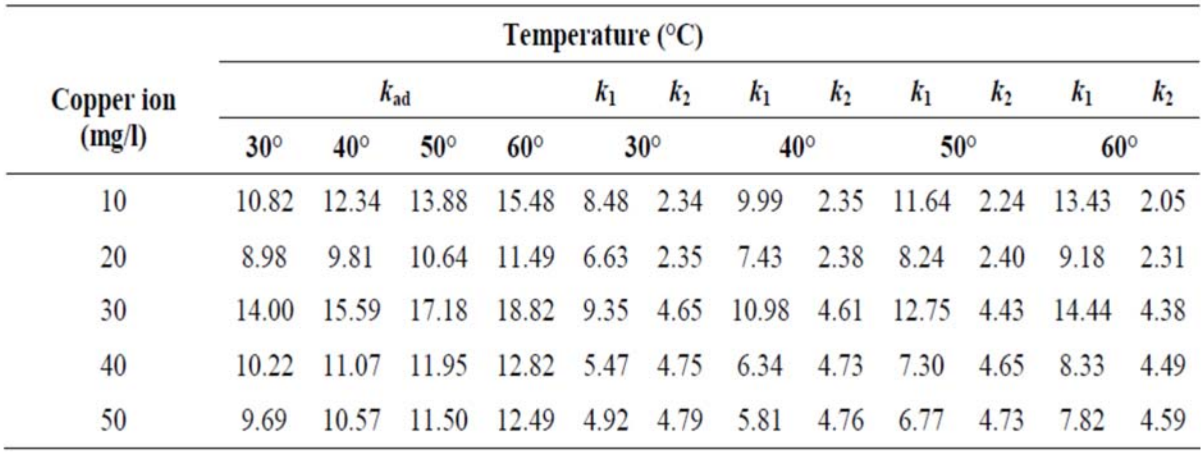
Where *k*1 is the forward rate constant and *k*2 is the backward rate constant. *A* represents the copper ion remaining in the aqueous solution and *B* represents the copper ion adsorbed on the surface of the activated carbon. The rate constants were calculated as earlier [11, 14, 16]. The data (Table 6) show that the forward rate constant is much higher than the backward rate constant, suggesting that the rate of adsorption is clearly dominant. At equilibrium, the rate is the ratio of the concentration of adsorbate in adsorbent and concentration of adsorbate in aqueous solution given by *K*0. The calculated values are presented in Table 7. The results indicates that *K*0 values decreases with increase in the concentration of the copper ion and increase with increase in temperature.

A clear examination of the effect of copper ion concentrations on the rate constant *K*ad (Table 6), the values help to describe the mechanism of metal ion removal taking place. In cases of strict surface adsorption, the variation of rate should be proportional to the first power of concentration. However, when pore diffusion limits the adsorption process, the relationship between initial copper ion concentration and rate of reaction will not be linear. This shows that pore diffusion limits the overall rate of copper ion adsorption [15, 17]. The contact-time experimental results can be used to study the rate-limiting step in the adsorption process, as shown by Weber and Morris [16–18]. Since the particles are vigorously agitated during the adsorption period, it is probably reasonable to assume that the rate is not limited by mass transfer from the bulk liquid to the particle external surface; one might then postulate that the rate-limiting step may be either film or intraparticle diffusion. As they act in series, the slower of the two will be the rate-determining step [16, 17]. The rate constant for intraparticle diffusion is obtained using the equation

$$Q = K_p t^{1/2} + C$$

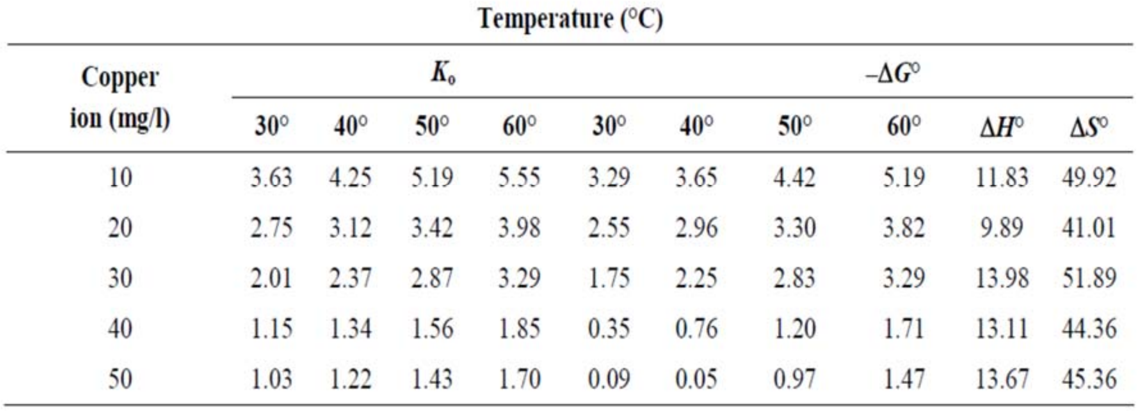
Here, *Kp*(mg/g/min) is the intraparticle diffusion rate constant. The *Kp*values obtained from the slope of the linear portions of the curves at metal ion concentration (Figure 3 and Table 8). The *Kp*values increased with increase in the copper ion concentration, which reveals that the rate of adsorption is governed by the diffusion of adsorbed copper ion within the pores of the adsorbent.

Table 6. Rate Constants for the Adsorption of Copper Ions ($10^3\ k_{ad}$, min^{-1}) and the Constants for Forward ($10^3\ k_1$, min^{-1}) and Reverse ($10^3\ k_2$, min^{-1}) Process



Copper ion (mg/l)	Temperature (°C)											
	k_{ad}				k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2
	30°	40°	50°	60°	30°		40°		50°		60°	
10	10.82	12.34	13.88	15.48	8.48	2.34	9.99	2.35	11.64	2.24	13.43	2.05
20	8.98	9.81	10.64	11.49	6.63	2.35	7.43	2.38	8.24	2.40	9.18	2.31
30	14.00	15.59	17.18	18.82	9.35	4.65	10.98	4.61	12.75	4.43	14.44	4.38
40	10.22	11.07	11.95	12.82	5.47	4.75	6.34	4.73	7.30	4.65	8.33	4.49
50	9.69	10.57	11.50	12.49	4.92	4.79	5.81	4.76	6.77	4.73	7.82	4.59

Table 7. Equilibrium Constant and Thermodynamic Parameters for the Adsorption of Copper Ions onto Acid Activated Carbon



Temperature (°C)										
Copper ion (mg/l)	K_o				$-\Delta G^\circ$					
	30°	40°	50°	60°	30°	40°	50°	60°	ΔH°	ΔS°
10	3.63	4.25	5.19	5.55	3.29	3.65	4.42	5.19	11.83	49.92
20	2.75	3.12	3.42	3.98	2.55	2.96	3.30	3.82	9.89	41.01
30	2.01	2.37	2.87	3.29	1.75	2.25	2.83	3.29	13.98	51.89
40	1.15	1.34	1.56	1.85	0.35	0.76	1.20	1.71	13.11	44.36
50	1.03	1.22	1.43	1.70	0.09	0.05	0.97	1.47	13.67	45.36

ΔH° (kJ/mol), ΔS° (J/K/mol), ΔG° (kJ/mol)

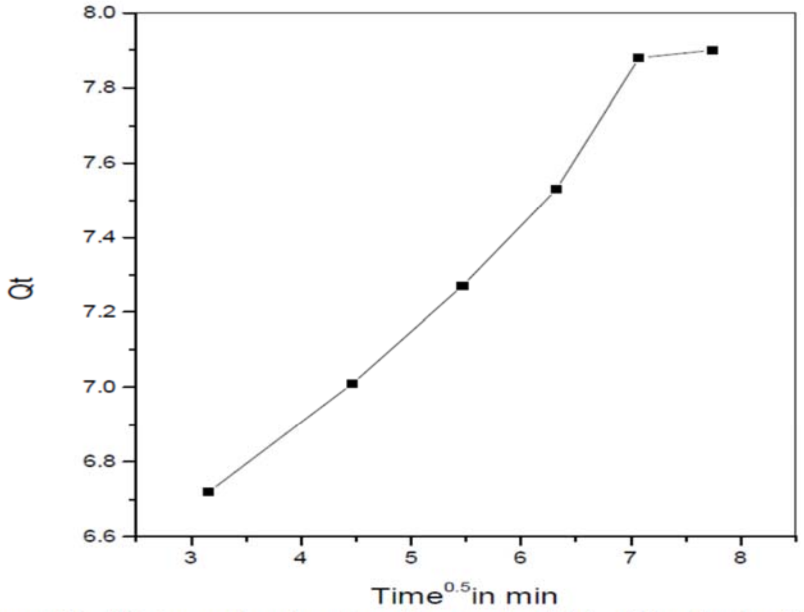


Figure 3. Effect of intraparticle diffusion on the adsorption of copper ion [Cu] = 10 mg/l; adsorbent dose = 50 mg/50 ml

3.6. Effect of Temperature

The adsorption capacity of the carbon increased with increase in the temperature of the system from 30°–60 °C. Thermodynamic parameters such as change in free energy ($\Delta G°$), enthalpy ($\Delta H°$), and entropy ($\Delta S°$) were determined using the following equations: [13, 15, 17, 18].

$$K_0 = C_{\text{solid}}/C_{\text{liquid}}$$

$$\Delta G^0 = -RT \ln K_0$$

$$\log K_0 = \Delta S°/(2.303RT) - \Delta H°/(2.303RT)$$

where*K*o 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. The $\Delta H°$ and $\Delta S°$ values obtained from the slope and intercept of the Van't Hoff plots have been presented in Table 7. The values are within the range of 1 to 93 KJ/mol indicating the favorability of physisorption. From the order, we could make out physisorption is much more favorable for copper ion. The positive values of $\Delta H°$ 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 copper ion adsorption increases, this rules out the possibility of chemisorption. However, the very low $\Delta H°$ value suggests copper ion is physisorbed onto adsorbent [16–19]. The negative values of $\Delta G°$ (Table 7) shows that adsorption is highly favorable for copper ion. However, it also indicates that the copper ion adsorption was spontaneous. The positive values of $\Delta S°$ (Table 7) shows the increased disorder and randomness at the solid solution interface of with adsorbent TCC. During the adsorption there are some structural changes in the copper ion and the adsorbent. The adsorbed water molecules, which have been 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 [5, 12, 18]. From the results, we could make out that physisorption is more efficient. Enhancement of the adsorption capacity of the activated carbon at higher temperatures has been attributed to the enlargement of pore size and activation of the adsorbent surface [13–15].

Table 8. Intraparticle Diffusion (K_p)

[Copper ion] (mg/l)	K_p
10	0.254
20	0.308
30	0.362
40	0.417
50	0.469

3.7. Effect of pH

The solution pH plays a major role in determining the amount of copper ions absorbed. Adsorption was studied over the range of pH ~ 3–10 and the results are shown in Figure 4. 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, which is 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

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

and taking only primary metal species expected to be formed in the working pH range into consideration, the species distribution diagrams for copper ion is constructed and given in Figure 4, It is evident that Cu ion 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 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 ion even at pH ~ 6.5 on the surface by nucleation cannot be neglected. At still higher pH (>7), however, part of Cu ion 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 ions with increased pH, is the pHZPC of TCC. At any pH below pHZPC the surface of metal oxides/ oxyhydroxides is positively charged and at pH above pHZPC the surface is negative. When the solution pH exceeded pHZPC, 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, 21].

3.8. Effect of Other Ions

Till now all the adsorption results discussed above were obtained by taking a single cation as adsorbate (*e.g.* Cu2+) However, in reality the contaminated water contains several other ions (both cations and anions) which canaffect the adsorption of heavy metals. Therefore, it was thought worthwhile to study the effect of some commonlyoccurring ions on the adsorption behavior of copper ion under present study. A typical water sample containingchloride ions, calcium ions and nitrate ions was doped with known quantities of adsorbate metal ions and thesesamples were used as the simulated water matrix for adsorption. A fixed amount of TCC was dispersed in this watermatrix containing adsorbate. The other adsorption parameters were kept constant, as stated earlier. The results are collected in Figure 5. It is evident that the presence of the above-mentioned ions in the adsorbate solution practically did not affect the extent of adsorption. It may be noted that almost the whole iron content in the adsorbate solution is removed after adsorption. The concentration of other ions, however, marginally decreased (within 10% of initial concentration) after adsorption. A higher concentration level of interfering ions may, however, adversely affect the adsorption capacity of TCC. Adsorption of different heavy metal from a simulated water matrix containing a high background level of different ions is being carried out to assess its future applicability to the removal of toxic metals from industrial effluents [16, 19, 20, 21].

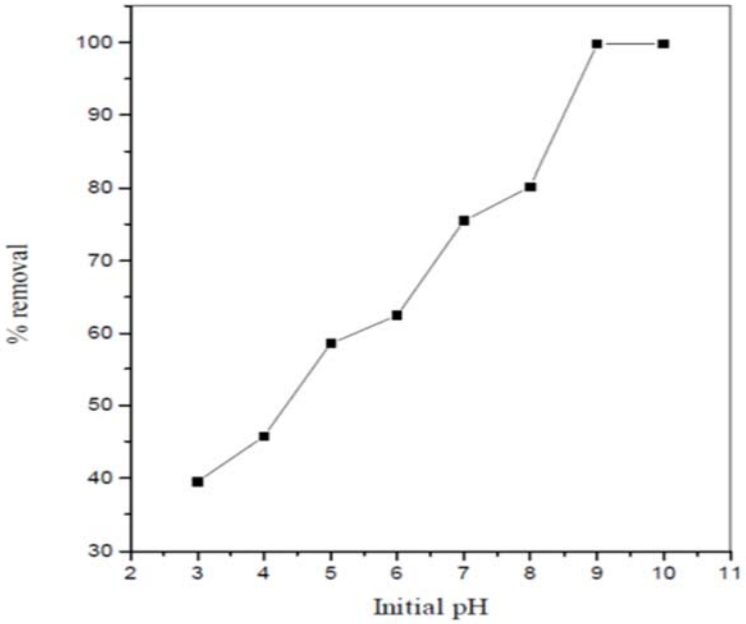


Figure 4. Effect of initial pH on the adsorption of copper ion [Cu] = 30 mg/l; adsorbent dose = 50 mg/50 ml; contact time = 60 min

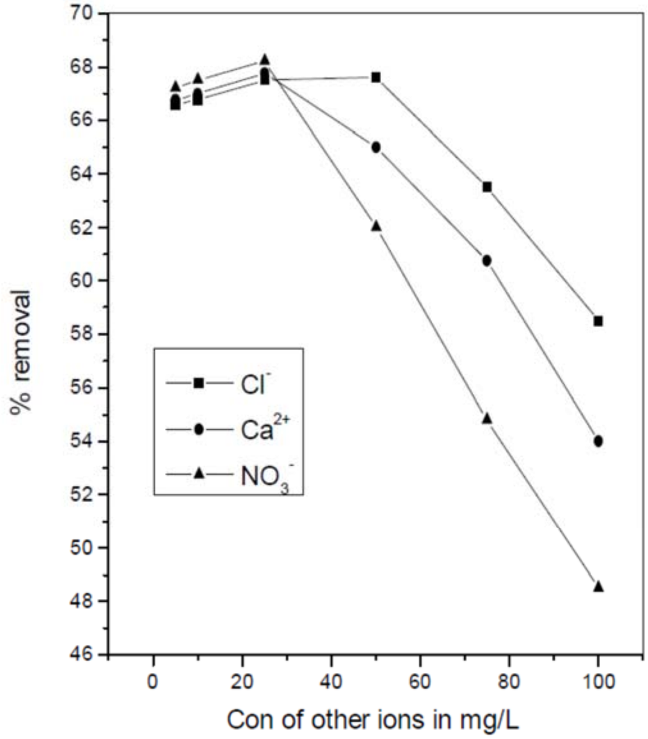


Figure 5. Effect of concentration of other ions on the removal of copper ion [Cu] = 30 mg/l; contact time = 60 min; Adsorbent dose = 50 mg/50 ml

3.9. Desorption Studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the copper ion. If the adsorbed copper ion can be desorbed using neutral pH water, then the attachment of the copper ion of the adsorbent is by weak bonds. If sulfuric acid or alkaline water desorp the copper ion, then the adsorption is by ion exchange. If organic acids, like acetic acid can desorp the copper ion, then the metal ion has held by the adsorbent through chemisorption. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 85% removal of adsorbed copper ion. The reversibility of adsorbed metal ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of metal ion by mineral acids and alkaline medium indicates that the copper ion was adsorbed onto the activated carbon through by physisorption mechanisms [15, 19, 20, 21].

4. Conclusions

The experimental data correlated reasonably well by the Langmuir and Freundlich adsorption isotherms and the isotherm parameters were calculated. The amount of copper ion adsorbed increased with increase in pH of the medium. The amount of copper ion adsorbed slightly decreased with increasing ionic strength and increased with increase in temperature. The dimensionless separation factor (R_L) showed that the activated carbon could be used for the removal of copper ion from aqueous solution. The values of $\Delta H°$, $\Delta S°$, and $\Delta G°$ results shows that the carbon employed has a considerable potential as an adsorbent for the removal of copper ion.

5. Acknowledgements

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6. References

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Biography

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His research topic includes & interested in Chemical Engineering, Environmental Engineering, Wastewater Treatment by Adsorption, Advanced Separation Process, Chemical Engineering Design, Mass Transfer, Chemical Process Synthesis, Chemical Engineering Thermodynamics etc.