

ADSORPTION AND KINETIC STUDIES OF COPPER (II) IONS REMOVAL FROM AQUEOUS SOLUTION BY ACTIVATED TYPHA ANGUSTATA.L CARBON -TiO₂ NANOCOMPOSITE

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Abstract

The present research work demonstrated removal of Copper (II) ions from an aqueous solution Typha Angustata L. It was characterized by Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX) and Fourier Transform Infrared (FTIR). The study was performed under different experimental conditions of initial metal ion concentrations, adsorbent dose, time and pH. The adsorption has been explained in the terms of Langmuir and Freundlich isotherm. The experimental data was found to obey with the Langmuir adsorption isotherm. This work suggests that the present Typha Angustata L can be more useful for the removal of copper from effluents discharged by industries.

Key terms:

Adsorption, Copper (II) ions, Typha Angustata L-TiO₂ nano composite, Langmuir, Freundlich, Adsorption isotherm, kinetics.

1. Introduction:

Rapid industrialization has led to increased disposal of wastewater into the environment. This often exceeds the admissible sanitary standards and results in the adverse impact on aquatic environment and consequently on human health. Wastewater treatment has received greater attention over the years due to the global awareness of the environmental deterioration. A large volume of effluent with hazardous species, namely heavy metals and semimetals, is being discharged every day from industries into aquatic systems [1]. Migration of Heavy metals into non contaminated areas as dust or leachates through the soil and spreading of heavy metals containing sewage sludge are a few examples of events contributing towards contamination of the ecosystems [2]. Most of heavy metals above trace quantities are harmful to humans, animals and plants. Federal and local agencies have therefore stipulated discharge limits on the levels of these heavy metals into the environment. In the course of tissue mineral research, copper toxicity is a common finding. By correlation thousands of tests with symptoms and diagnosis, a picture has emerged of the detrimental effects of copper toxicity on human health as well as on aquatic environment. Copper toxicity is much overlooked because of many important health conditions like fatigue, premenstrual syndrome, anorexia, depression anxiety, migraine headache, and allergies [3]. In mammals due to copper toxicity wide range of effects such as liver cirrhosis, necrosis in kidneys and the brain, gastrointestinal distress, lesions, low blood pressure, and fetal mortality are found [4–6]. Too much copper in water may damage marine and freshwater organisms such as fish and molluscs [7]. It also interferes with the sense of smell in fish, thus preventing them from choosing good mates or finding their way to mating areas [8]. A variety of conventional methods can be used for the removal of copper from an effluent which includes membrane filtration [9], chemical precipitation [10], electro coagulation [11], reverse osmosis [12], solvent extraction [13], biological degradation [14], ion exchange [15] and adsorption [16]. Most of these methods suffer from some drawback, such as the high capital or high operational cost or the disposal of the resulting sludge [17]. Among these techniques, adsorption is generally preferred due to its high efficiency, easy handling, and availability of different adsorbents. So the search for cost-effective adsorbents has become the focus of attention for many studies [18]. The present study focused upon adsorption of copper metal from its aqueous solution by Typha Angustata L with various heavy metal ions in aqueous medium.

2. Materials and Methods

2.1 Preparation of activated carbon (AC)

Typha Angustata L from flowers collected were cut into small pieces, washed thoroughly to remove dust using deionized water, dried under shadow for 25 days, then they were dried in an oven at 120°C for 6 hours. The dried material of the Typha Angustata L flowers were then taken in a steel vessel and heated in a muffle furnace. The temperature was raised gradually up to 500°C and kept it for half an hour. The carbonized material was ground well and sieved to different particle size. It was stored in a plastic container for further studies. It was labeled as activated carbon. In this study particle size of 0.15 to 0.25mm were used.

2.2 Preparation of Activated Carbon–TiO₂ Nano Composite (AC- TiO₂ - NC):

3gms of activated carbon was kept to contact in 15ml of water free alcohol for 2 hours at 25°C and stirred to get a uniform suspension. At the same time 3gms of titanium dioxide was dispersed into water free alcohol the diluted TiO₂ was slowly added into the suspension of activated carbon and stirring for further 5 hours at 25°C then 5mL of free alcohol is mixed with 2ml of deionized water and added slowly and stirring was further continued for another 5 hours at 25°C. Then the suspension was kept overnight for 10 hours at room temperature and the precipitate obtained was carefully dehydrated in an vacuum oven for 6 hours at 80°C. The resulting composite material was labeled as AC-TiO₂-NC. The nanoparticle size of this composite was proved by XRD using Scherer formula. Both AC and AC-TiO₂-NC were stored in airtight container and characterized.

3. Results and Discussion

3.1 Characterization of Adsorbents

The physico-chemical properties of the chosen of the two adsorbents (AC and AC-TiO₂-NC) were compared. The morphology and functional group of the surface of the adsorbents were studied with SEM, XRD, EDX and FT-IR.

3.1.1 Scanning Electron Micrograph (SEM)

The size of pore distribution of activated carbon is one of the critical factors determining its applicability in the adsorption process. The SEM images of activated carbon and Nano composite are shown in Figures 1(a and b). The SEM image of the activated carbon exhibiting heterogeneous pitted surface and wide varieties of pores present in the activated carbon nano composite.

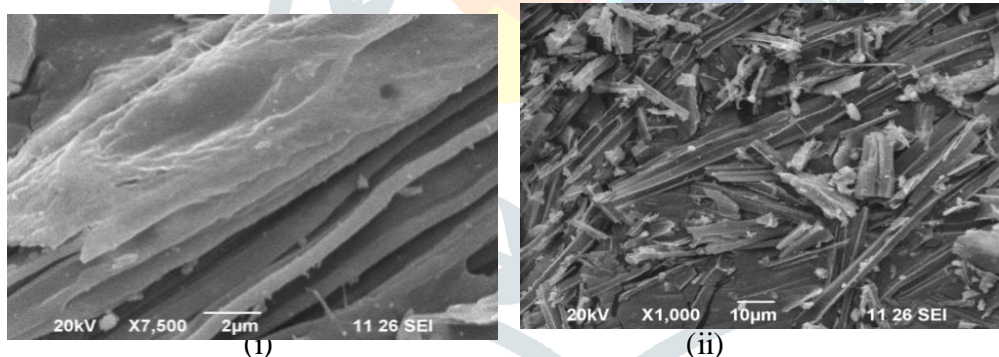


Figure 1a: SEM image of A C

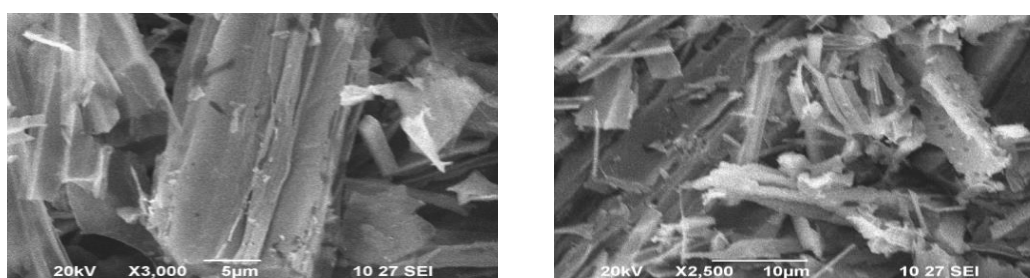


Figure 1b: SEM image of AC-TiO₂-AC

3.1.2 XRD Analysis

X-ray diffraction technique is a powerful tool to analyse the change in molecular and crystalline structure of the adsorbent. Crystalline materials give well defined peaks where as non- crystalline or amorphous materials show sharp peaks .It appears from the XRD pattern that the AC and AC- TiO₂- NC prepared amorphous in nature which are presented in Figures 2(a and b).

In Figure 2a the XRD pattern of Activated Carbon reveals that peaks occur at $2\theta = 28.3^\circ$ and 66.4° . Figure 2b the diffraction peak can positioned at $2\theta = 29.6^\circ$ and 69.1° . The appearance of peak at $2\theta=29.6^\circ$ indicate that the activated carbon and nano composite were predominantly amorphous in nature. The size nano particles of the composite are proved by XRD using scherer formula

$$D = \frac{K\lambda}{\beta \cos\theta} \text{-----(1)}$$

Where D is crystalline average size, K is constant (usually between 0.9 to 1.0) λ is X-ray wave length (1.54 \AA), β is full maxima half width, θ is diffraction angle.

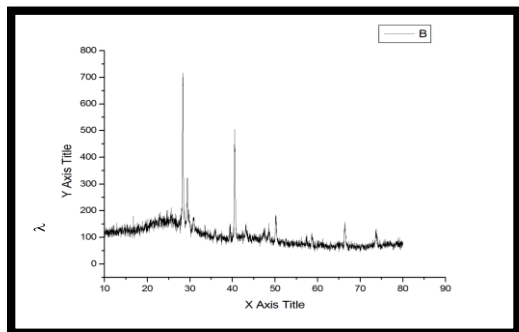


Figure 2a: XRD Pattern of AC

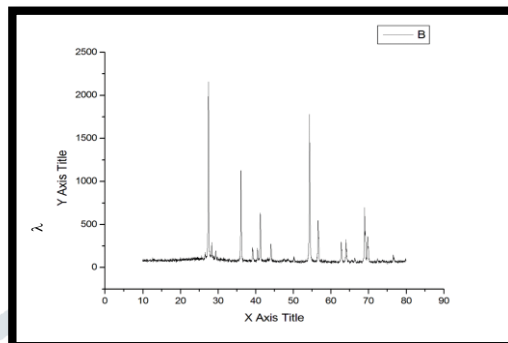


Figure 2b: XRD Pattern of AC-TiO₂-NC

3.1.3 Energy –disperse X-ray Spectroscopic (EDX) Analysis :

The EDX pattern of activated carbon and activated carbon TiO₂ nano composite are shown in Figure 3(a and b). The percentage weight of the elements Carbon, Oxygen, Sulphur, Sodium, Magnesium, Phosphorous, Potassium, Calcium and Chloride are 88, 7.54, 0.13, 0.23, 0.13, 0.35, 2.19, 0.23 and 1.23% respectively are evidently shown by Figure 3a.

Figure 3b is the EDX Pattern of AC–TiO₂–NC. From the Figure it is observed that the percentage weight of the elements Carbon, Oxygen, Sodium, Magnesium, Phosphorous, Sulphur, Chlorine, Potassium, Calcium and Titanium are 88, 7.51, 0.23, 0.13, 0.35, 0.13, 1.23, 2.19, 0.23 and 89% respectively.

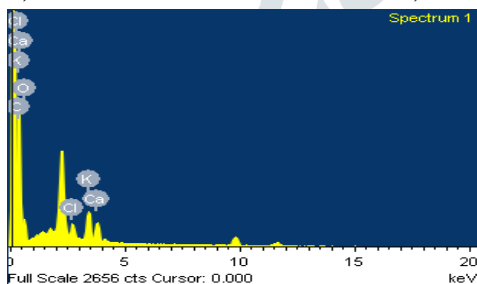


Figure 3a: EDX Pattern of AC

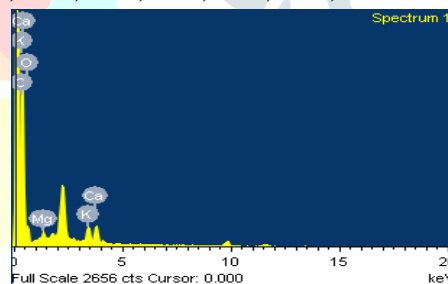


Figure 3b :EDX Pattern of AC-TiO₂-NC

3.1.4 Fourier Transform Infra Red Spectroscopy

The FT – IR Spectroscopy is used to identify the functional groups present in the surface of the adsorbent which are shown in the Figures 4(a and b) . The peaks obtained at $2850.88, 2924.18 \text{ cm}^{-1}$ and 2960.83 cm^{-1} belong to C-H stretching vibration in the CH₂ and CH₃ groups. The band appearing at 1925.02 cm^{-1} and 1996.39 cm^{-1} show the stretching frequency for C=O group in carboxylic acid. All these bands clearly confirmed the presence of –OH, C=O, C-H, CH₂ and CH₃ groups in the adsorbent.

In Figure 4b the peak occurs at 3524.35 cm^{-1} may be for the band of N-H. The band occurs at 617.22 cm^{-1} and type of band C-H and 655.80 cm^{-1} is present C-H bonding, the weak band appears at $434.22, 460.35 \text{ cm}^{-1}$ and 510.42 cm^{-1} are attributed to Ti-O vibrations.

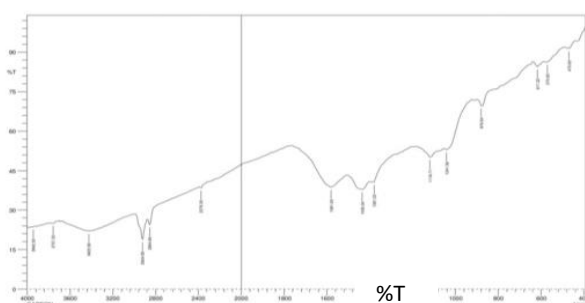


Figure 4a: FT-IR Spectrum of AC

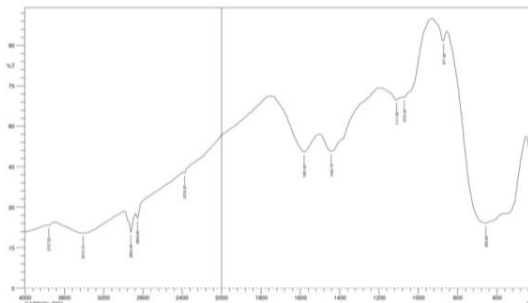


Figure 4b: FT-IR Spectrum of AC- TiO₂-NC

3.2 Batch Adsorption Experiment

Batch adsorption studies were performed at room temperature (30°C) for all the aqueous solution of metal ions selected. Studies such as adsorbent dose, p^H , agitation concentration and contact time were conducted. The use of the adsorbent for continuous use was also determined by adsorption studies.

Copper(II) Stock solution (1000 ppm)

A stock solutions of Copper(II) were prepared by dissolving appropriate amounts of 3.929g of ($CuSO_4 \cdot 5H_2O$) in deionized water.

Determination of Copper(II)

Copper(II) was determined spectrophotometrically using ethylene diamine. A suitable aliquot of the solution containing less than 50 μ g of Copper(II) was transferred into a 25mL standard flask. 2.0mL each of ammonia was added. The solution was diluted up to the mark with double distilled water and the absorbance was measure at 460 nm against a blank solution. Calibrations graph for 0.50% μ g of Copper(II) was prepared and the concentration of Cu (II) in the sample aliquot was established by referring to the calibration graph. All required concentrations were prepared by proper dilution the stock solution. Metal ions concentrations were determined using different wave length with an double beam UV- visible spectrophotometer.

3.2.1 Effect of agitation time and initial metal ion concentration

The effect of agitation time and initial metal ion concentration on the removal of Copper(II) with four different concentration (10,20,30 and 40ppm) on the adsorbent (AC and AC-TiO₂-NC) was investigated under all the experimental conditions. The experimental results are given in the Table and in the Figures 5(a and b). From these Figures it is observed that the percentage colour removal decreases with increase in contact time with increase in initial metal ion concentration of all the metal ions studied.

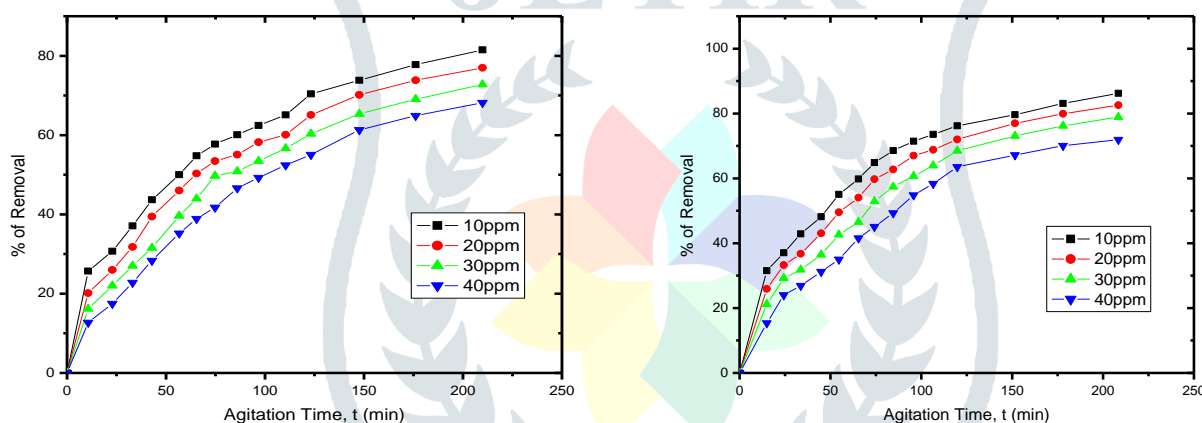


Figure 5a: Effects of agitation time and initial metal ion concentration on the removal of Copper(II) onto AC

Figure 5b: Effects of agitation time and initial metal ion concentration on the removal of Copper(II) onto AC-TiO₂-NC

3.3 Adsorption kinetic studies

For the study of adsorption kinetic, metal ion solutions of different initial concentrations (10, 20, 30, 40 ppm) with a fixed weight of the adsorbent (100 mg/50 mL) were taken. Adsorption kinetic shows large dependence on the physical characteristics of the adsorbent material AC and AC-TiO₂-NC that also influence the adsorption mechanism. The data from equilibrium studies were applied to different kinetic models, viz., pseudo first order, pseudo second order, Elovich and intra-particle diffusion. Suitable kinetic model for adsorption was assessed based on the agreement between the values of q_e calculated, q_e experimental, regression coefficients, R^2 and sum of squares of errors, SSE obtained from suitable plots for the above models.

3.3.1 Pseudo first-order kinetic model

The transient behavior of the batch sorption process at different initial metal ions concentration was analyzed using the Lagergren's pseudo first order kinetic model. This was the first kinetic model for the adsorption of liquid/ solid system based on the solid capacity and was used extensively to describe the sorption kinetics.

The linear form of this model proposed by Lagergren is

$$\frac{dq_t}{dt} = k_1(q_e - q_t) \text{-----} (2)$$

Where q_e/q_t are the amounts of metal ions adsorbed at equilibrium (mg/g) and at time t(min) and k_1 is the rate constant of the Pseudo first order adsorption process/(min⁻¹). After integration by applying conditions, $q_t=0$ to $q_t=q_t$ and at $t=0$ to $t=t$. In its logarithmic form the equation (2) can be modified as

$$\log(q_e - q_t) = \log q_e - \left(\frac{k_1}{2.303}\right)t \text{-----} (3)$$

The kinetic parameters for the Pseudo first order for adsorption of the metals studied on both AC and AC-TiO₂-NC presented are in Table 1 From the Figures 6(a and b),the linearity of the plots at various initial concentrations of metals suggested that the process did not follow first order kinetics

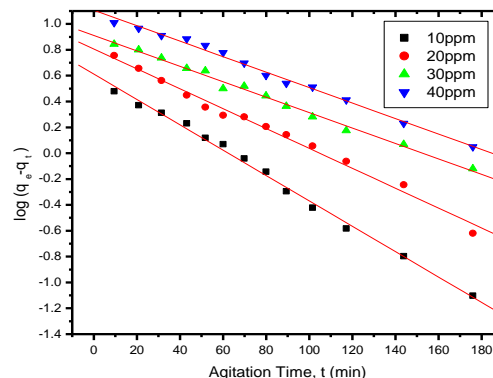
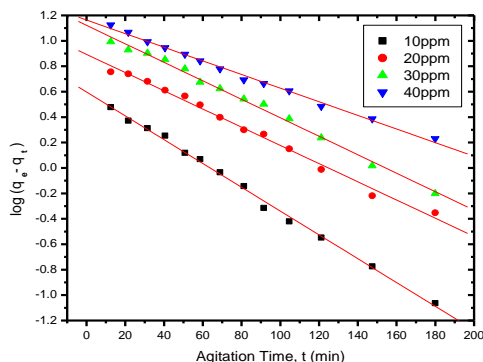


Figure 6a: Plot of the Pseudo-First order kinetic model of Copper(II) onto AC Figure 6b: Plot of the Pseudo-First order kinetic model of Copper (II) onto AC-TiO₂-NC

Table 1: Consolidated table for Pseudo first order kinetics

Metal ions	Conc. of metal ion mg/L	AC					AC-TiO ₂ -NC				
		q _e .exp (mg/g)	q _e cal (mg/g)	k ₁ x10 ⁻² (min ⁻¹)	R ²	SSE	q _e .exp (mg/g)	q _e cal (mg/g)	k ₂ x10 ⁻³ (g/mg/min)	R ²	SSE
Copper(II)	10	4.668	4.460	3.462	0.694	0.590	4.704	5.808	4.162	0.963	0.837
	20	8.321	6.934	1.768	0.862	4.235	8.512	15.059	1.880	0.972	5.222
	30	14.248	9.729	1.985	0.775	4.791	11.248	20.097	2.081	0.954	5.379
	40	13.324	13.231	1.640	0.885	5.335	14.671	25.104	1.724	0.994	5.511

3.3.2 Pseudo-second order kinetics

The adsorption kinetics may be described by pseudo second order model based on the equilibrium capacity is expressed as

$$\frac{dq_t}{dt} = k_2(q_e - q_t) \text{-----} (4)$$

From Figures.7(a and b) it is observed that the plots of t/q_t against t give straight lines at the whole contact time for all the initial metal ions concentrations studied,suggesting that the adsorption process followed the pseudo second order kinetics with the entire adsorption time which supported the assumption for the model that the adsorption is due to chemisorptions.

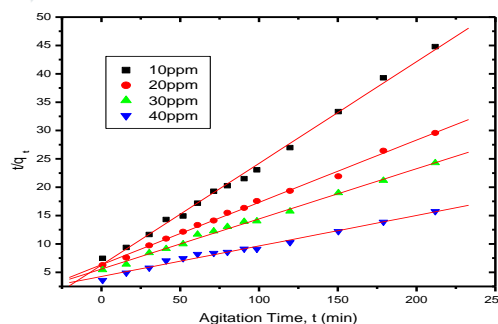
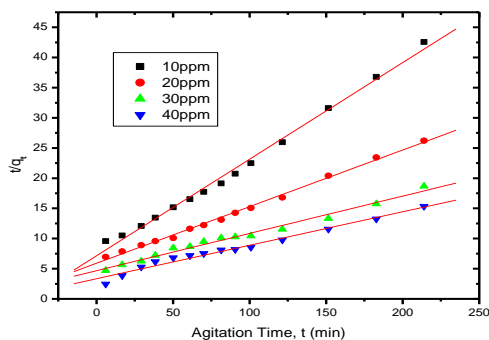


Figure 7a: Plot of the Pseudo-second order kinetic model of Copper(II) onto AC Figure 7b: Plot of the Pseudo-second order kinetic model of Copper (II) onto AC-TiO₂-NC

Table 2: Consolidated table for Pseudo second order kinetics

Metal ions	Conc. of metal ion mg/L	AC					AC-TiO ₂ -NC				
		q _e exp (mg/g)	q _e cal (mg/g)	k ₂ X10 ² (g/mg/min)	R ²	SSE	q _e exp (mg/g)	q _e cal (mg/g)	k ₂ X10 ⁻³ (g/mg/min)	R ²	SSE
Copper(II)	10	4.66	6.73	0.019	0.99	1.89	4.70	7.23	0.028	0.99	1.91
	20	8.32	9.10	7.855	0.99	4.16	8.51	9.51	12.044	0.99	4.55
	30	14.2	14.9	4.193	0.99	7.74	11.2	15.2	6.530	0.99	7.74
	40	13.3	20.2	2.342	0.99	3.10	14.6	20.7	3.641	0.99	3.96

3.3.3 Intraparticle Diffusion Model

The structure of the solid and its interaction with the diffusion of the substance influence the rate of transport. Intra particle diffusion is a transport process involving movement of species from the bulk of the solution to the solid phase. When the diffusion of metal ions occur inside the adsorbent the rate limiting step, then the adsorption data can be given by the intraparticle diffusion kinetic model which can be represented in the following form as reported by Weber and Morris in 1963.

$$q_t = \frac{K_i dt_1}{2} + C \text{ -----(5)}$$

To evaluate the applicability of each kinetic model equation, the sum of error squares(SSE) is calculated using the formula.

$$\%SSE = \frac{\sqrt{\sum(q_{e(exp)} - q_{e(cal)})^2}}{N} \text{ ----- (6)}$$

Where N is the number of data points.

Generally, all the metals adsorbed onto AC and AC-TiO₂-NC follows Pseudo second -order kinetics due to their best agreement of q_e(exp) with q_e(cal), values of R² closer to unit and low SSE values.

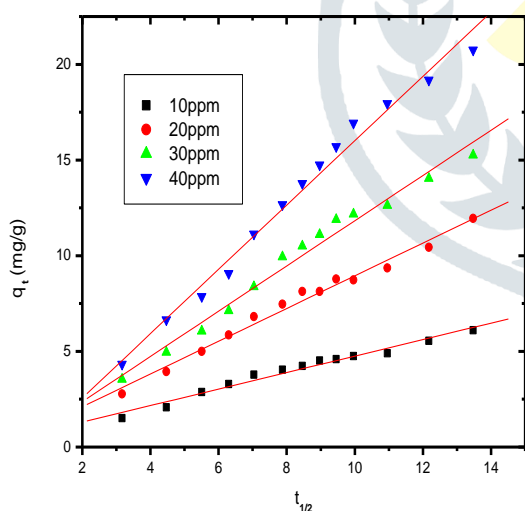


Figure 8a: Plot of the Intraparticle diffusion kinetic model of Copper(II) onto AC

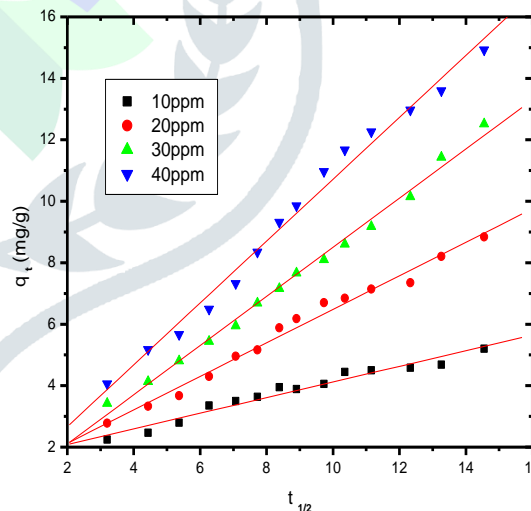


Figure 8b: Plot of the Intraparticle diffusion kinetic model of Copper(II) onto AC-TiO₂-NC

Table 3: Consolidated table for Intraparticle diffusion studies

Metal ions	Conc. of Metal ion (mg/L)	AC					AC-TiO ₂ -NC				
		q _e exp (mg/g)	q _e cal (mg/g)	K	R ²	SSE	q _e exp (mg/g)	q _e cal (mg/g)	K	R ²	SSE
Copper(II)	10	4.668	5.674	0.183	0.981	0.320	4.704	5.267	0.191	0.996	0.479
	20	8.321	5.285	0.388	0.985	0.678	8.512	8.930	0.439	0.985	0.715
	30	14.248	10.485	0.621	0.995	0.845	11.248	4.090	0.663	0.993	1.124
	40	13.324	14.759	0.927	0.998	1.140	14.671	15.239	0.935	0.987	1.299

3.4 Effect of Adsorbent dose and Initial metal ions concentration on Removal of metals from Aqueous Solutions

The dependence of metals adsorption on both AC and AC-TiO₂-NC, as a function of adsorbent dosage was studied by varying the amount of carbon from 0.01 to 0.1g per 50mL of the metal solution, by keeping all other parameters (pH, agitation speed and equilibrium time) constant for the initial metal ion concentrations of 10, 20, 30 and 40ppm and the experimental values

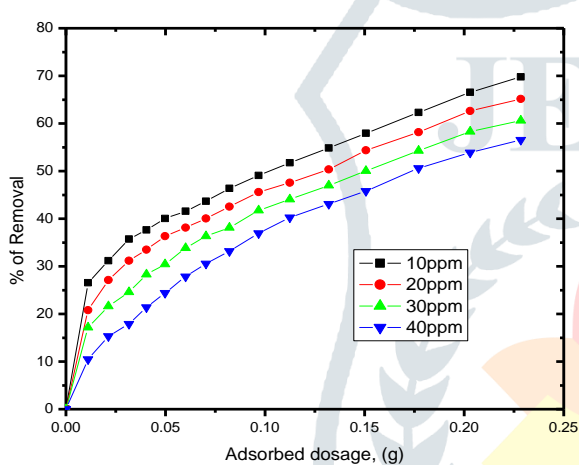


Figure 9a: Effect of Adsorbent dose and Initial metal ion concentration of Copper(II) onto AC

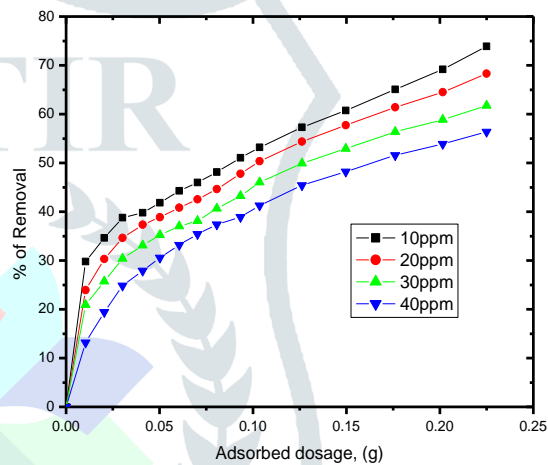


Figure 9b: Effect of Adsorbent dose and Initial metal ion concentration of Copper(II) onto AC-TiO₂-NC

3.5 Effect of pH on the adsorption metal ion solution

pH is one of the most important parameters in controlling the extent of heavy metal ion uptake from their aqueous solutions. Figure 10(a and b) shows the effect of pH on the percentage removal of heavy metal. The removed of metal influenced by the pH. The maximum removal percentage of metal ion occurred at pH 9.

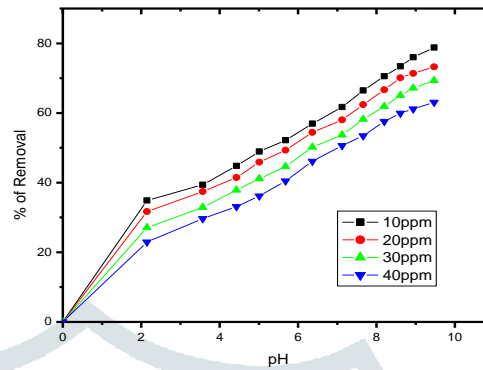
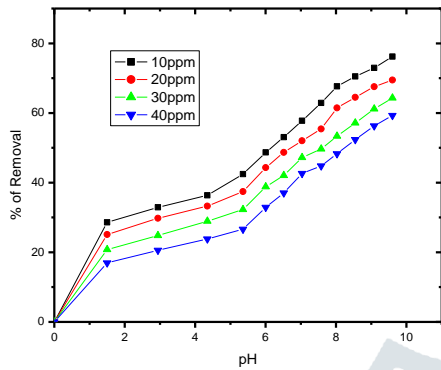


Figure 10a: Effect of pH and Initial metal ion concentration of Copper(II) onto AC Figure 10b: Effect of pH and Initial metal ion concentration of Copper(II) onto AC-TiO₂-NC

3.6 Desorption studies

In order to probe further into the mechanistic aspects of AC and AC-TiO₂-NC based sorption desorption studies were conducted. These studies were conducted with distilled water at different pH values, using sodium chloride, hydrochloric acid and acetic acid. It may be inferred from the desorption data that the molecules of the metal ion are bound to the surface of AC and AC-TiO₂-NC by a strong interaction due to chemisorption.

3.7 Adsorption Isotherm

Adsorption properties and equilibrium data, commonly known as adsorption isotherms, which describes how adsorbate interact with the adsorbent materials and show how they are critical in optimizing the utility of adsorbents. There are several isotherm equations available for analyzing experimental sorption equilibrium data. In this work the experimental data were tested in Langmuir, Freundlich and Tempkin isotherm models.

3.7.1 Langmuir Isotherm model

The Langmuir adsorption isotherm model is widely used to describe the adsorption progress from a liquid solution and investigate mechanism of adsorption.

The linear form of Langmuir isotherm is ,

$$\left(\frac{C_e}{q_e}\right) = \left(\frac{1}{bQ_0}\right) + \left(\frac{C_e}{Q_0}\right) \text{-----(7)}$$

Where K_L and a_L are the Langmuir constants.

The favourability of the adsorption process can be expressed in terms of dimensionless separation factor R_L calculated using the relation,

$$R_L = \frac{1}{1 + bC_0} \text{.....(8)}$$

For adsorption on both AC and AC-TiO₂-NC, the R_L values are found to be between 0 and 1 for all the metal ions which confirmed the ongoing adsorption process were favorable.

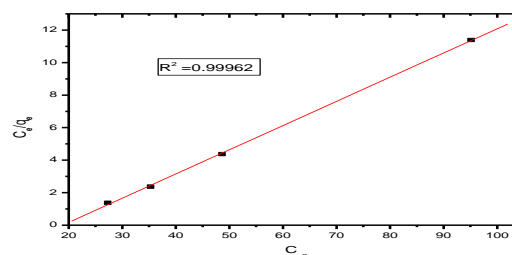
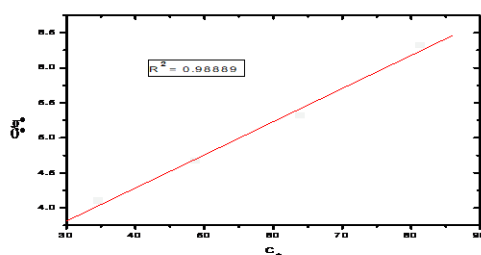


Figure 11a: Langmuir plot for the adsorption of Copper(II) onto AC

Figure 11b: Langmuir plot for adsorption of Copper(II) AC-TiO₂-NC

Table 4: Data for Langmuir Adsorption Isotherm for Copper(II) onto both AC and AC-TiO₂-NC

Metal ion mg/L	AC				AC-TiO ₂ -NC			
	R _L	b(L/mg)	Q ^o (mg/g)	R ²	R _L	b(L/mg)	Q ^o (mg/g)	R ²
60	0.0889	0.1701	16.129	0.9888	0.2399	0.0528	6.75	0.9996
80	0.0682				0.1914			
100	0.0553				0.1592			
120	0.0465				0.1363			

3.7.2 Freundlich Isotherm model

The Freundlich model was applicable to a solid with energetically heterogeneous surfaces in monolayer coverage. The well known logarithmic form of the Freundlich isotherm is given by the equation .

$$\log q_e = \log k_f + \frac{1}{n} \log C_e \text{-----(9)}$$

Experimental observations of the present study indicate that the adsorption data agree very well with both Langmuir and Freundlich isotherms with both adsorbents used for the metal ion studied. The applicability of both Langmuir and Freundlich isotherms to the adsorption of metals on both adsorbents showed that both monolayer adsorption and heterogeneous conditions exist under the experimental conditions used in this study. The values correlation coefficient R² of all metal ions for both AC and AC-TiO₂ -NC adsorbent follows Freundlich isotherm model.

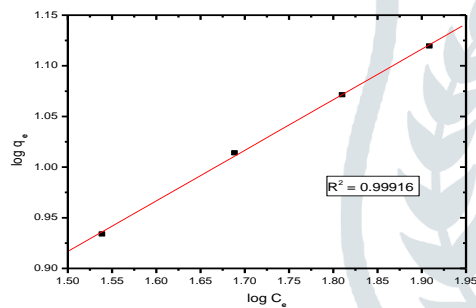


Figure 12a: Freundlich plot for the adsorption of Copper(II) onto AC

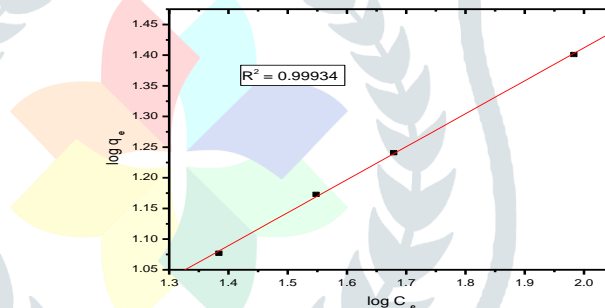


Figure 12b: Freundlich plot for the adsorption of Copper(II) onto AC-TiO₂-NC

Table 5: Freundlich constants for metal ions adsorption onto both AC and AC-TiO₂-NC

Metal ions	AC			AC-TiO ₂ -NC		
	K _f (mg/g)	N	R ²	K _f (mg/g)	n	R ²
Copper(II)	18.06	1.776	0.9991	20.31	1.859	0.9993

3.7.3 Temkin Isotherm model

Temkin considered the effects of some indirect adsorbent/adsorbate interactions on the adsorption isotherms. This isotherm is based on the fact that if the concentration is not too low or too high, because of the interactions between the adsorbate and adsorbent, the heat of adsorption of all the molecules in a layer decreases linearly with coverage and that the adsorption is characterized by a uniform distribution of the binding energies up to a maximum. The linear form of Temkin isotherm equation, commonly applied is in the following form .

$$Q_e = \left(\frac{RT}{bT}\right) + \ln(A_T C_e) \text{----- (10)}$$

The Temkin isotherm equation can be simplified to the following form.

$$q = B_T \ln A_T + B_T \ln C_e \text{-----(11)}$$

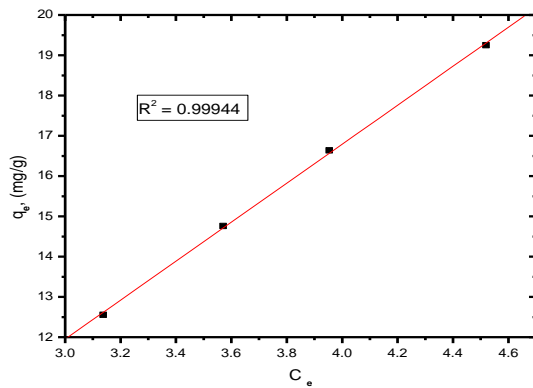


Figure 13a: Tempkin plot for the adsorption of Copper(II) onto AC

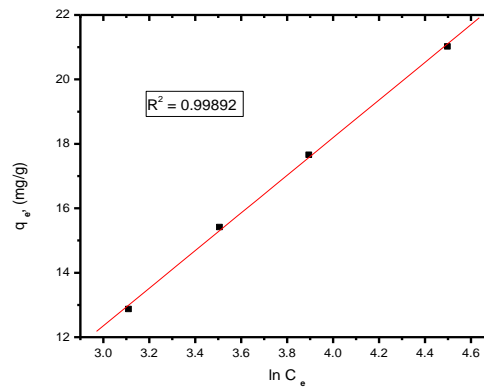


Figure 13b: Tempkin plot for the adsorption of Copper(II) onto AC-TiO₂-NC

Table 6: Tempkin constants for metal ions adsorption onto both AC and AC-TiO₂-NC composite

Metal ions	AC			AC-TiO ₂ -NC		
	K _T	B _T	R ²	K _T	B _T	R ²
Copper(II)	8.80	280.88	0.999	45.16	185.57	0.998

3.8 Effect of temperature on the removal of metal ions from aqueous solution

The effect of temperature on the adsorption of metals, the studies were conducted at four different temperatures (30°C, 34°C, 38°C to 42°C), by agitating the initial metal ions concentration of 40ppm of all the metal ions studied with 100mg/50mL of two adsorbents. From the experimental data and the figures it is observed that removal of metals increases with increase in temperature on the two adsorbents.

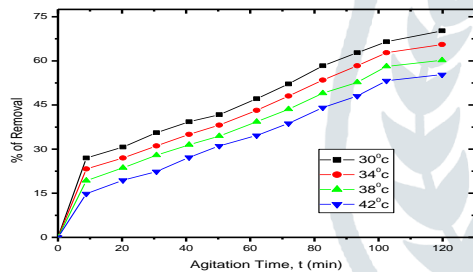


Figure 14a: Effect of Temperature and removal of Copper(II) onto AC

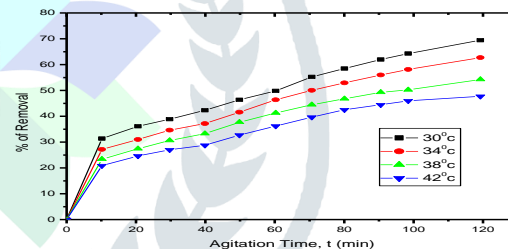


Figure 14b: Effect of Temperature and removal of Copper(II) onto AC-TiO₂-NC

3.9 Evaluation of thermodynamic parameters

Batch adsorption studies were carried out with individual metals at their natural pH on both AC and AC-TiO₂-NC by varying the temperature range (30°C to 60°C). Using the equilibrium data presented in Table 7 thermodynamic parameters were evaluated. The adsorption thermodynamic parameters namely change in Gibbs free energy, ΔG° , change in Enthalpy of adsorption, ΔH° and change in entropy of adsorption ΔS° are determined from adsorption affinity, $\ln(q_e \cdot m/C_e)$. ΔH° and ΔS° were determined from the slope and intercept of linear plot of $\ln(q_e \cdot m/C_e)$ Vs $1/T$ using Eyring's equation Figure 15(a and b).

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \text{-----(26)}$$

Where, ΔS° is the standard entropy change; ΔH° is the standard enthalpy change; ΔG° is the Gibbs free energy change.

The calculated ΔS° and ΔH° values for different temperatures 33°C to 44°C using equations 25 and 26 are presented in Table 16.

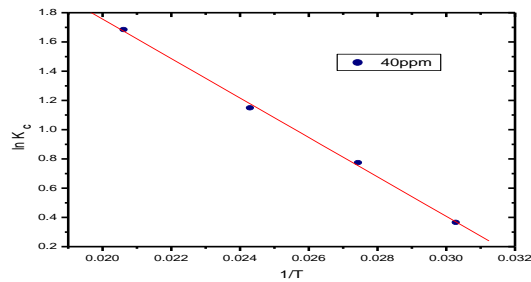


Figure 15a: Effect of Temperature and removal of Copper(II) onto AC

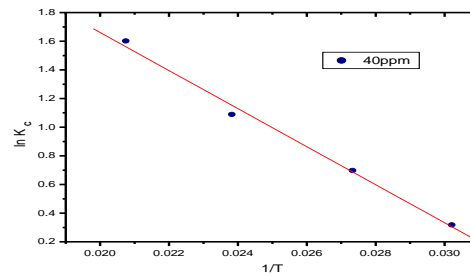


Figure 15b: Effect of Temperature and removal of Copper(II) onto AC-TiO₂-NC

Table 7: Consolidated data for Thermodynamics of parameters for adsorption of metal ions

Metal ions	AC				ΔS° (J/K/mol)	ΔH° (kJ/mol)	AC-TiO ₂ -NC				ΔS° (J/K/mol)	ΔH° (kJ/mol)
	$-\Delta G^\circ$ (kJ/mol)						$-\Delta G^\circ$ (kJ/mol)					
	303 K	307 K	311 K	315 K			303 K	307 K	311 K	315 K		
Copper(II)	59.1	59.1	64.5	51.3	99.51	51.31	76.9	55.9	61.9	66.8	115.65	54.98
	2	6	1	6			8	4	5	4		

4. CONCLUSION

The chemically prepared activated Typha angustata L carbon can be used as a best material for the removal of Copper (II) ions from the industrial waste water. Pyrolytic method was used to synthesis activated carbon from the flowers and the nanocomposite was prepared of solvothermal method. Batch adsorption studies were carried out to find out the effect of adsorption such as parameters agitation time and initial metal ions concentration, adsorbent dose, initial p^H and temperature on the removal of metal ions using the adsorbents prepared. Langmuir, Freundlich isothermal models were significant correlation with adsorption equilibrium data. The adsorption of Copper(II) ions follows Pseudo-second order and controlled by Intraparticle diffusion models.

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