



COMPARATIVE STUDIES OF THE BIOSORPTION OF IRON USING TEA LEAVES (*cammelia sinensis*) AND TEA FIBRE AS ADSORBENTS



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Abstract

Globally, industrial waste contamination of water bodies has posed a serious environmental problem. This research aimed to investigate the sorption of iron using tea leaves and fibers as adsorbents. The parameters investigated were; contact time, dosage of adsorbent, pH, temperature, and starting concentration which provide information about kinetics, thermodynamics, and equilibrium conditions of the sorption system. For both adsorbents, the maximum sorption capacity occurs within 35-40 minutes, with the best sorption pH ranging from 5-7. Likewise, the dosage of adsorbent and initial concentration of adsorbate has maximum sorption capacity occurring from 3-4 mg and 40-50 mg/L respectively. There was a step increase in % removal as the temperature increased with maximum activity occurring at 60 to 70 °C for both adsorbents. The pseudo first-order model best described the kinetics, providing the most convincing fit with R² values of 0.9915, 0.9983, 0.9982, and 0.986 respectively. The Langmuir model provided a better fit for explaining the system's equilibrium state, with R² values of 0.8177 for tea fiber and 0.9637 for tea leaf. The calculated thermodynamic parameters for tea fiber (-9550 kJmol⁻¹, -9709 kJmol⁻¹, -9868 kJmol⁻¹ and -10026 kJmol⁻¹) and tea leaf (-6829 kJmol⁻¹, -6944 kJmol⁻¹, -7059 kJmol⁻¹ and -7174 kJmol⁻¹) confirm the system's feasibility, spontaneity, and disorderliness under viable adsorption conditions.

Keywords: thermodynamics, adsorption, kinetics, tea leaves, tea fibers, Isotherms.

Introduction

Environmental waste management has contributed a lot towards enhancing and maintaining purity in our habitat. Various systems of waste management have been in practice and proven effective, as at the time industrialization was still at its infancy. Today, the world sees industrialization as a positive indicator of progress, an agent of civilization, but it is also accompanied by a number of environmental issues that pose significant health risks. Until heavy metals, which were a major component of most industrial effluents, were discharged, many water bodies were considered safe for domestic use. Contaminated bodies of water containing toxic metals are channeled to surface water, endangering aquatic life and other living organisms and posing a serious threat to food security. Various industrial processes, such as petrochemical refining, prolonged mining, and electroplating activities in the steel industry, are at the forefront, and as a result, scientists from all over the world are concerned about how to address this problem (Akhtar *et al.*, 2004).

Bio-sorption is the most commonly used technology for waste water purification due to its economic and simple nature under viable sorption conditions. Adoption of techniques such as reverse osmosis, membrane filtration, iron exchange, and solvent extraction (Onen *et al.*, 2017; Song, 2017) has been difficult in recent years due to the cumbersome nature of the techniques as well as the economic demands that come with conditions. For example, selecting a suitable solvent for the extraction of a specific component can be difficult because not all solvents have the ability to extract a specific solute; thus, the solute's solubility in the chosen solvent must be of utmost importance. In the case of sorption, the technique is primarily dependent on the

pore size of the adsorbent that can be occupied by an adsorbate; thus, any material that can be activated can fit in as long as it has appreciable pore size and sorption functional groups.

Biosorbents are materials created by subjecting plant and animal products to intense heating in the absence of oxygen, followed by activation with an acid or a base. Once prepared, the increased pore space or the emergence of suitable binding sites that may allow interaction with the adsorbate in question can be attributed to an increase in sorption potency. Most natural products are potential adsorbents that can be used to eliminate the presence of metallic toxins such as nickel in wastewater; this is because most plants and plant products contain lignin and cellulose, both of which have electronegative binding sites that are easily attracted by electropositive species (Serencam *et al.*, 2008). Plants are generally given the consideration status and thus, the savior of our dear planet in this regard.

Camellia sinensis is an angiosperm dicot plant that produces tea from its leaves and buds. It is a member of the *Camellia* genus and the *Theaceae* family. Its origins can be traced back to China and Asia (Dupler, 2001), but it is now grown all over the world in both tropical and subtropical climates. When cultivated for its leaves, the strong tap-rooted shrub is evergreen and usually cut to less than 2 meters in height. The flowers are about 4 cm in diameter, and the petals are either seven or eight yellow in color. Tea oil can be extracted from the seeds of *C. sinensis* (Xia *et al.*, 2017). The fresh leaves, which contain about 4% caffeine, are 4-15 cm long and 2-5 cm wide. (Xia *et al.*, 2017).

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Fig :1 *Camellia sinensis* plant

Tea plants (*Camellia sinensis*) are grown primarily for the purpose of producing the beverage drink known as tea. The majority of the plant has been used for this purpose. This study uses plant leaves and fibers as adsorbents to remove iron from simulated waste water, demonstrating that some low-cost agricultural waste can be used as effective adsorbents.

Methodology

Preparation of Stock Solution

About 0.1 M of iron II sulfate with MW=151.908g/mol). It was prepared by weighing 15.19 g of iron II sulfate powder into 100 cm³ water in a beaker. It was stirred and transferred into a 1000 cm³ volumetric flask and made up with distilled water up to the mark. (Etim *et al.*, 2019)

Preparation of different Concentrations of Metal Solutions

Various concentrations 20 mg/L, 30mg/L, 40 mg/L, and 50 mg/L of iron solutions were prepared from the stock solution as specified according to the methods of Etim *et al.*, (2019).

Investigations

The investigation with tea leaves and fibre (*Camellia sinensis*) as an adsorbent for the elimination of nickel metal ions from a simulated nickel solution with the consideration of various constrains such as initial concentration, pH, temperature, contact time and biosorbent dosage was carried out according to the methods of Etim *et al.*, (2019). The tea leaves and fibers were collected from Saradauna local Government area of Taraba State, using the method according to Etim *et al.*, (2022) for sample collection and preparation. They were washed, rinsed, sun dried for seven days, pulverized, filtered via a 150mm sieve and finally stored in an airtight container prior to experiments including such parameters as initial concentration, pH, adsorbent dose, and temperature and contact time. The equilibrium relationship was accessed as a function of the effects of the parameters as investigated in these studies.

Metal Uptake Evaluation

The technique according to Madhavi *et al.*, (2021) was used to estimate the metal uptake q_e . This was done using the following equation;

$$q_e = \frac{V(C_o - C_e)V(C_o - C_e)}{m \quad m}$$

Where q_e = metal ions per dry biosorbent (mg/g)
 V = volume of solution (L)
 C_o = initial concentration of metal in solution (mg/L)

C_e = final concentration of metal in solution (mg/L)
 m = the mass of biosorbent (g)

The total Percentage Removal

The total percentage removal is given by the equation

$$\frac{C_o - C_e}{C_o} \times 100$$

% metal removed =

Adsorption Kinetics

Good understanding of diffusion mass transport or kinetics process for different adsorbents is of paramount importance. Thus, models such as pseudo first and second-order models were employed to analyze kinetics data for the sorption process.

Pseudo-first order kinetics model

The linearized pseudo-first order kinetics is expressed as:

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} t$$

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} t$$

Where

q_e Stand for the quantity of metal uptake at equilibrium point,

q_t Stand for the quantity adsorbed at any instant of time t

k_1 Stand for the pseudo-first order constant t stands for the initial time.

A plot of $\log(q_e - q_t)$ versus t should yield a linear connection if the pseudo-first order is applicable. The slope and intercept of the curve can be used to derive the constant k_1 and projected q_e , respectively.

Pseudo-second order kinetics model:

Integrated rate equation for second order kinetic model is given as:

$$\frac{1}{q_e} = \frac{1}{k_2 q_t^2} + \frac{1}{q_e} t$$

Where

q_e = the metal uptake

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q_t/q_t = amount adsorbed at any instant of time t
t = the initial time

The plot of $\frac{1}{q_e q_e}$ against t will give a straight line whose slope is equal to the rate constant k_2, k_2 .

Adsorption Isotherms

Langmuir Isotherm

The Langmuir isotherm model was determined using the equation below, which depicts the relationship between the quantities (mg/g) of adsorbate adsorbed on the adsorbent and the adsorbate concentration (mg/L) in solution at equilibrium condition.

$$\frac{C_e}{q_e} = \frac{1}{bQ_0} + \frac{C_e}{Q_0}$$

Where

C_e = the equilibrium concentration (mg/L)

q_e = the amount of adsorbate adsorbed on the adsorbent at equilibrium

b = the langmuir isotherm constant (L/mg)

Q_0 = the adsorption capacity of the adsorbents.

Freundlich Isotherm

Freundlich isotherm demonstrate that the adsorption process on a heterogeneous adsorbent, surface is multilayered, and the adsorption sites have varying degree of attraction for the adsorbate. These isotherm model was determined using the following equation below;

$$\log q_e = \log k_f + \frac{1}{n} \log C_e$$

$$\log q_e = \log k_f + \frac{1}{n} \log C_e$$

Where

$K_f K_f$ = Freundlich isotherm constant (mg/g or dm³/g) associated with adsorbent adsorption capacity

n = the adsorption intensity related to the heterogeneity of the adsorbent surface

A plot of $\log q_e$ against $\log C_e$ gives a straight-line of slope

$$\frac{1}{n}$$

and an intercept equal to $\log k_f k_f$

Thermodynamics of Adsorption

The nature of an adsorption process is confirmed by the evaluation of its thermodynamic parameters.

Thermodynamic parameter like free energy change ($\Delta\Delta$

G_{ads}), enthalpy change ($\Delta\Delta H_{ads}$) and entropy change (Δ

ΔS_{ads}) of adsorption were calculated to evaluate the feasibility and spontaneity of the process.

The standard free energy change of adsorption ($\Delta\Delta G_{ads}^\circ$) was calculated using the following equation below;

$$\Delta\Delta G_{ads}^\circ = -2.303RT \log(bQ_0) \\ = -2.303RT \log(bQ_0)$$

The maximal langmuir adsorption capacity is Q_0 and the langmuir isotherm constant is b.

T is the thermodynamic temperature and R is the gas constant (8.314 J mol⁻¹ K⁻¹).

The Gibbs free energy of biosorption can be computed (Din *et al.*, 2014) as follows;

$$\Delta\Delta G^\circ = -RT \ln K_c$$

Where $\Delta\Delta G^\circ$ represents the standard Gibb's free energy change for the adsorption (J/mol), R represents the universal gas constant (8.314 J/mol/K) and T represents the temperature (K). The adsorbate's distribution coefficient is K_c . A negative Gibbs free energy value suggest that the adsorption process is feasible and spontaneous (Din *et al.*, 2014)

The plot of $\ln K_c$ versus 1/T yields a straight line with values

for $\Delta\Delta H^\circ$ and $\Delta\Delta S^\circ$ as the slope and intercept.

K_c is the distribution constant and can be written as (Salman *et al.*, 2015)

$$K_c = \frac{C}{C_{ad}} = \frac{C}{C_e}$$

C_{ad} (mg/l) and C_e (mg/l), respectively, are the concentration of solute adsorbed at equilibrium and the concentration of solute in solution at equilibrium.

The following is the relationship between (ΔG°), enthalpy change (ΔH°) and entropy change (ΔS°) of adsorption:

$$\Delta\Delta G^\circ = \Delta\Delta H^\circ - T \Delta\Delta S^\circ$$

Positive change in enthalpy (ΔH°) implies that the adsorption is an endothermic process, but positive change in entropy (ΔS°) reflects enhanced randomness at the solid/ solution interface.

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Results and Discussion

Table.1 Effect of biosorbent dosages for the removal iron on tea leaves and tea fiber

Adsorbent	Dosage(g)	Co(mg/l)	Ce(mg/l)	Qe(mg/g)	%R
Fiber	1	30	0.600	1.47	98.00
	2	30	0.500	0.74	98.33
	3	30	0.400	0.49	98.67
	4	30	0.200	0.37	99.33
Leaves	1	30	0.500	1.49	98.33
	2	30	0.400	0.74	98.67
	3	30	0.300	0.49	99.00
	4	30	0.200	0.37	99.33

As expressed in Figs. 1 and 2, increase in dosage of the adsorbent results in an increase in the sorption capacity. This can be explained by the emergence of more functional groups as well as available binding sites for the sorption of the iron metal ions present in the simulated medium. Both

plant parts show adequate activity with the maximum activity for the tea fibre at 3g while that of the tea leaves continues to some extent which is in consonance with the result reported by Etim *et al.*, (2019).

Table.2 Effect of pH on tea fiber and leaves

Adsorbent	pH	Co(mg/l)	Ce(mg/l)	Qe(mg/g)	%R
FIBER	1	30	0.600	1.470	98.00
	3	30	0.400	1.480	98.67
	5	30	0.300	1.485	99.00
	7	30	0.100	1.495	99.33
LEAVES	1	30	0.600	1.470	98.00
	3	30	0.500	1.475	98.33
	5	30	0.400	1.480	98.67
	7	30	0.300	1.485	99.00

The efficiency of this system at pH 1–7 expressed in percent shows that the removal for tea fiber (between 98 and 99 %) was almost in consonance with that of the tea leaves (between 98 and 99 %). There was an observable increase in electrostatic repulsion as the pH increases thus little amount

of positive charges are available for competition resulting in increase in sorption. Presence of OH⁻ ions may have little or no effect on the sorption of the metal ions at very high pH this is true because the binding sites on the adsorbent do not allow much interaction with the hydroxyl specie

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Table3. Effect of contact time on tea fiber and tea leaves

Adsorbent	Time(mins)	Co(mg/l)	Ce(mg/l)	Qe(mg/g)	%R
Fiber	10	30	0.700	1.465	97.67
	20	30	0.600	1.470	98.00
	30	30	0.400	1.480	98.67
	40	30	0.200	1.490	99.33
Leaves	10	30	0.400	1.480	98.67
	20	30	0.300	1.485	99.00
	30	30	0.200	1.490	99.33
	40	30	0.1	1.495	99.67

As shown in figs 5 and 6, as the time in which the adsorbent is brought in contact with the adsorbate is increased, the activities increased and then begins to retard at some particular time interval. The metal uptake which was

investigated between 10-40 minutes show a slowdown in activity at exactly 20 minutes for both tea fiber and the tea leave. This result agrees with the report of Bansal *et al.*, (2009).

Table.4 Effect of temperature

Adsorbent	temperature	Co(mg/l)	Ce(mg/l)	Qe(mg/g)	%R
Fiber	40	30	0.400	1.480	98.67
	50	30	0.300	1.485	99.00
	60	30	0.200	1.490	99.33
	70	30	0.100	1.495	99.67
Leaves	40	30	0.600	1.470	98.00
	50	30	0.500	1.475	98.33
	60	30	0.400	1.480	98.67
	70	30	0.200	1.490	99.33

The equilibrium condition for iron(ii) ions uptake by the leaves and fibre of tea plant occurs under the influence of temperature. This was more viable with the tea fibre compare to the tea leaves. The sorption process at

equilibrium decreases with increase in temperature due to the formation of adsorbate – adsorbent complex most likely to be unstable at high temperature conditions with the solid phase decomposing into the bulk solution.

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Table.5 Effect of initial concentration on tea leaves and tea fiber.

Adsorbent	Co	Ce	Qe	%R
Fiber	20	0.800	0.960	96.00
	30	0.800	1.465	97.33
	40	0.500	1.475	98.75
	50	0.300	2.485	99.40
Leaves	20	0.600	0.970	97.00
	30	0.400	1.480	98.67
	40	0.300	1.985	99.25
	50	0.100	2.495	99.80

As shown in Figs. 9 and 10, the sorption of iron (ii) ions by both tea fibre and tea leaves shows the same trend under the initial concentration constraint, even though the process increased rapidly with tea fibre and then slowly with tea

leaves. This can be seen as the function of the driving force of the concentration gradient with respect to increase in initial metal ion concentration as reported by Kalavathy and Miranda (2010).

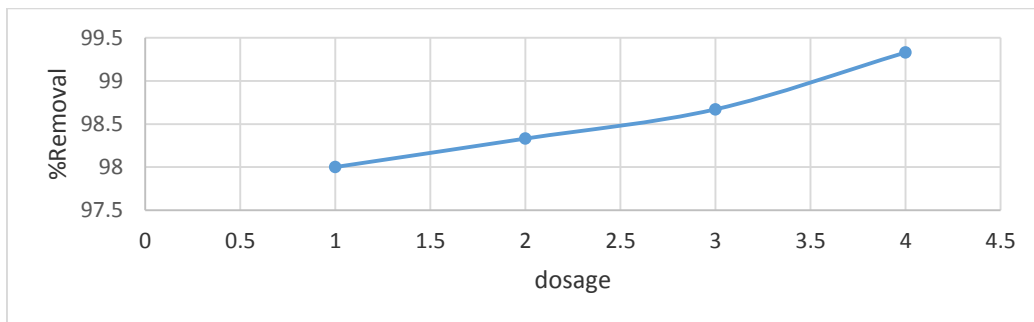


Figure 1 Effect of biosorbent dosage on tea fiber

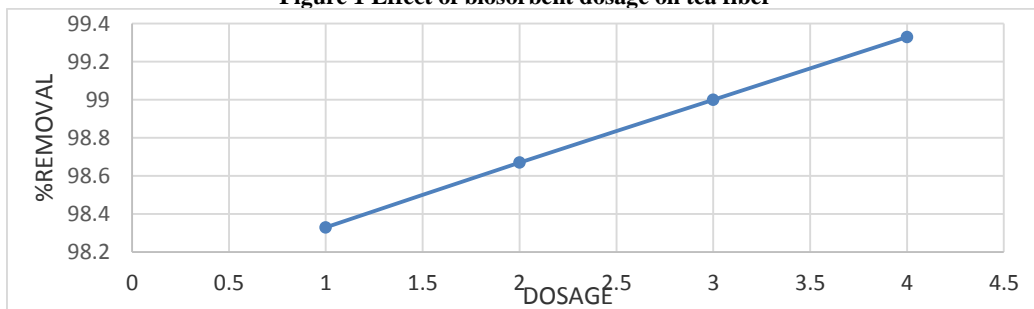


Figure 2. Effect of biosorbent dosage on tea leaves

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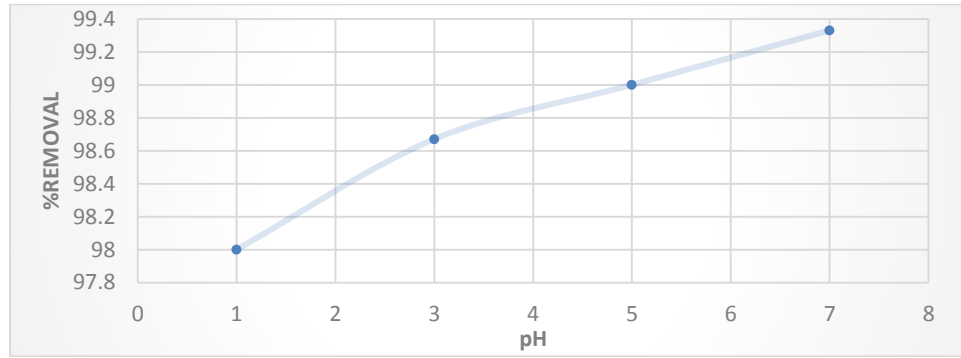


Figure 3. Plot of %removal verses pH on tea fiber

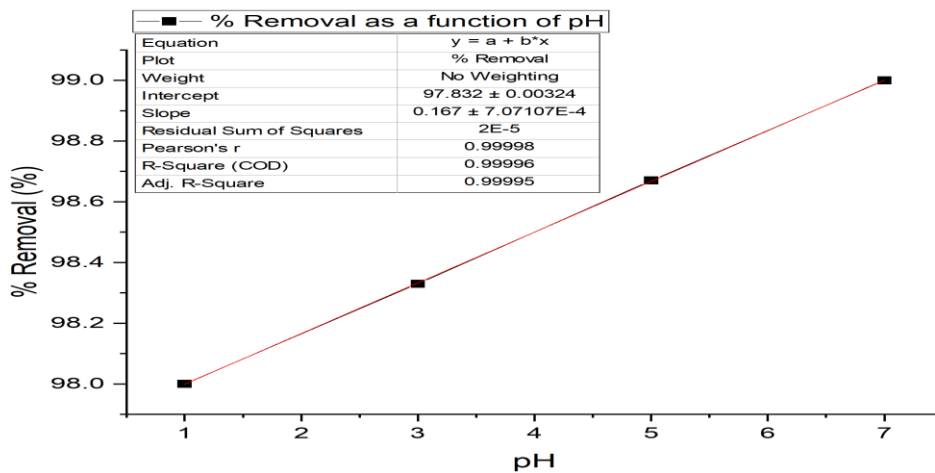


Figure 4. Plot of %removal verses pH for tea leaf

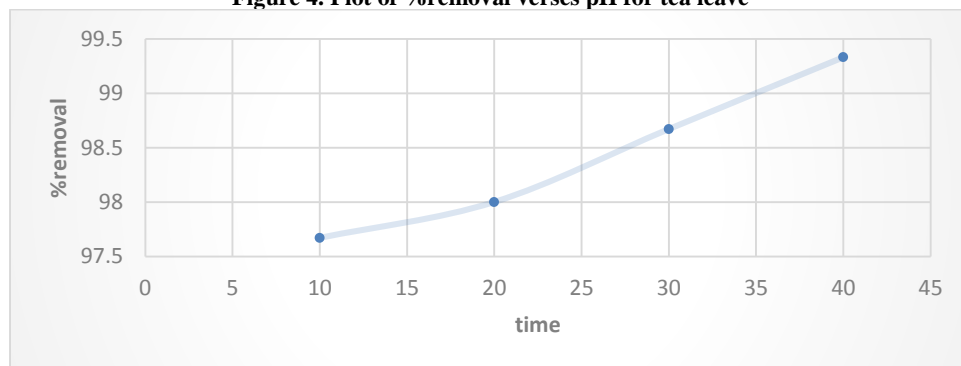


Figure 5. Plot of %removal verse time of tea fiber

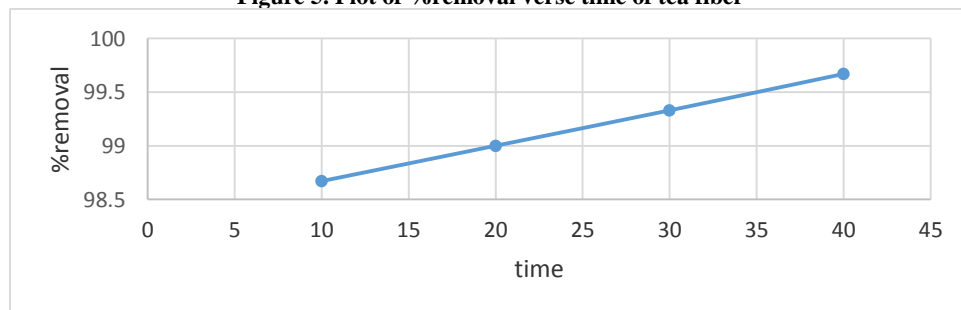


Figure 6. Plot of %removal against time for tea leaves

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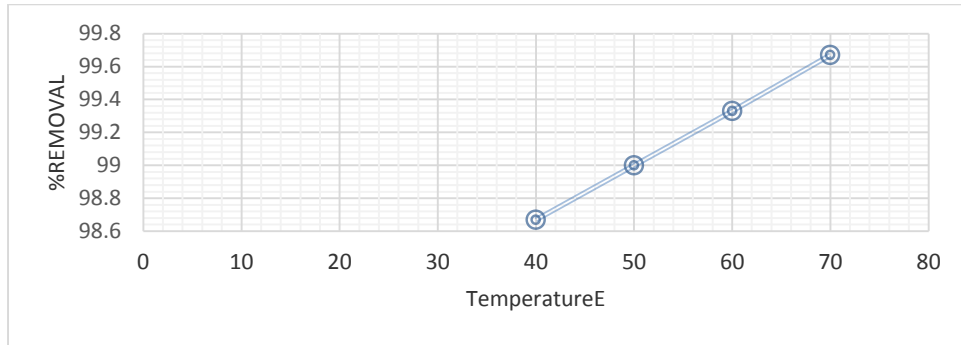


Figure 7. Effect of temperature on tea fiber.

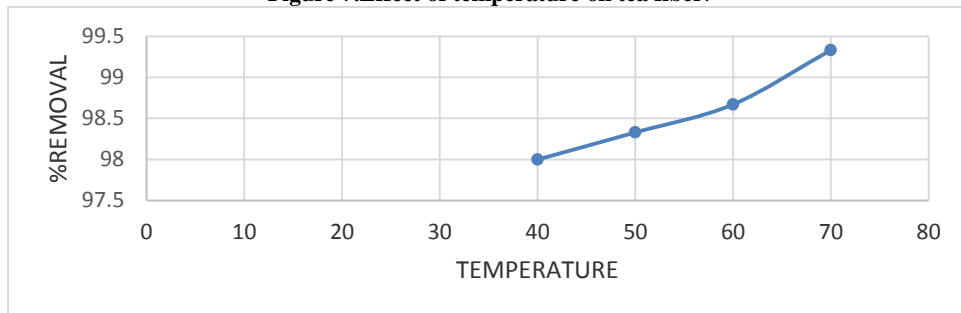


Figure 8. Effect of temperature on tea leaves.

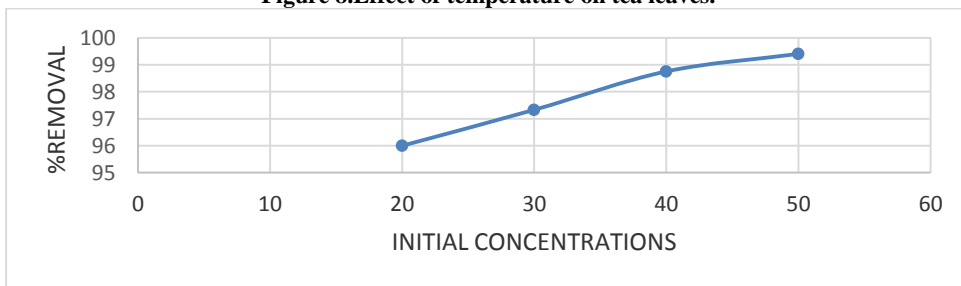


Figure 9. Effect of initial concentration on tea fiber.

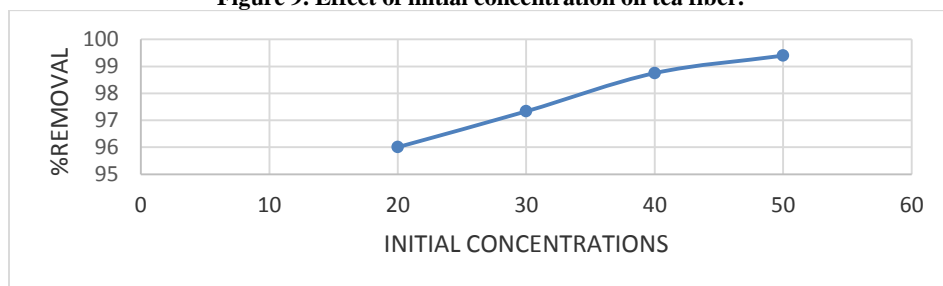


Figure 10. Effect of initial concentration on tea leaves.

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Kinetic Studies of Tea Leaves and Tea Fiber

Table 6: Kinetic studies of tea fiber and tea leaves.

adsorbent	Time	Ce	Qe	Log(qe-qt)	t/qt	%R
fiber	10	0.700	1.465	-0.116	14.3	97.67
	20	0.600	1.470	-0.060	33.3	98.00
	30	0.400	1,480	0.033	75.0	98.67
	40	0.200	1.490	0.111	200.0	99.33
leaves	10	0.400	1.480	0.033	25.0	98.67
	20	0.300	1.485	0.074	66.67	99.00
	30	0.200	1.490	0.111	150.0	99.33
	40	0.100	1.495	0.145	400	99.67

With the help of batch adsorption kinetics, modeling and design operations for sorption of iron metal by tea leaves and fibre has been progressively ascertained. The operating constraints as well as the physical and chemical properties of the adsorbents provide information about the nature of the

sorption kinetics of both parts of the tea plant with the metal ion. From Figs. 11, 12, 13 and 14 we can see that the kinetics followed both pseudo first and second order kinetics with pseudo first order kinetics given the best fit for the sorption of iron(ii) ions by both tea leaves and fibre.

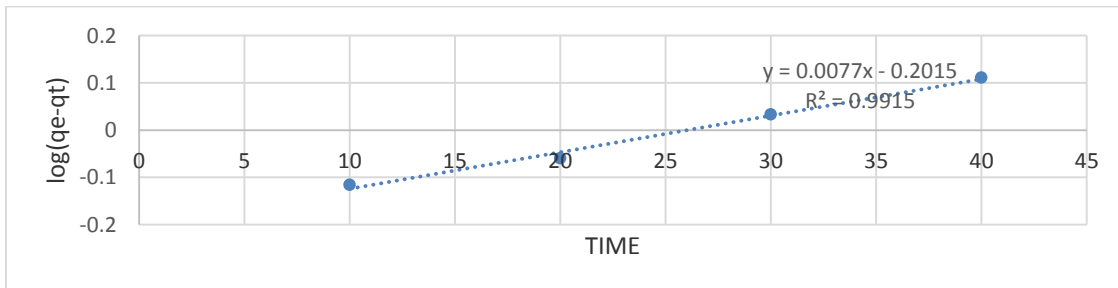


Figure 11. Pseudo first order reaction of tea fiber.

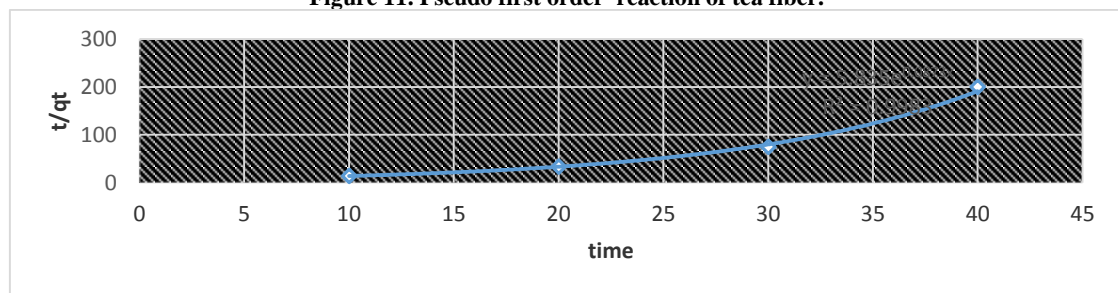


Figure 12. Pseudo second order of tea fiber.

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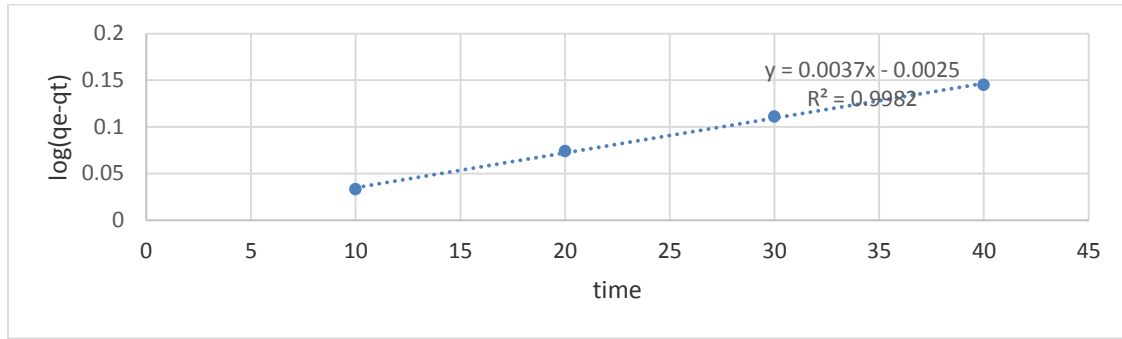


Figure 13. Pseudo first order of tea leaves

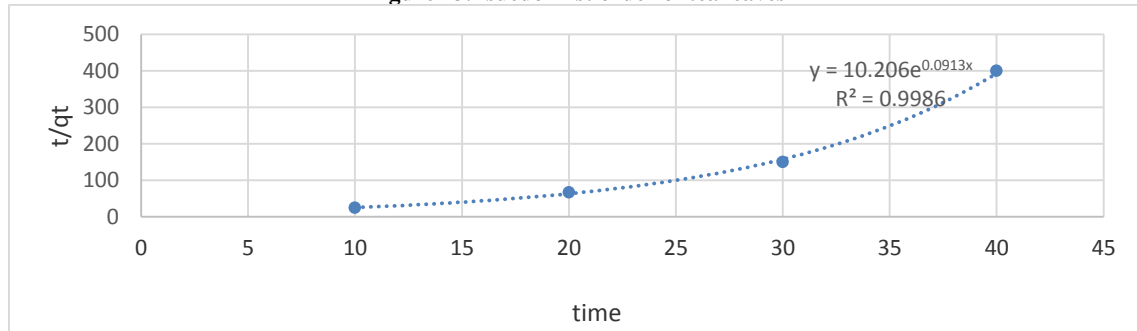


Figure 14. Pseudo second order of tea leaves.

Application of Pseudo First Order Kinetics Equation

Applying equation:

Pseudo first order

$$\frac{2.3032.303}{a} \log \frac{a-x}{a-x}$$

$$K_1 = \frac{t}{a-x} \log \frac{a-x}{a-x}$$

Pseudo second order

$$K_2 = \frac{1}{t} \frac{x}{a(a-x)}$$

Table 7. Kinetic for first order of tea fiber

Time	k ₁	S.D
10	0.00024	0.00047
20	0.00101	
30	0.00045	
40	0.00017	

Table 8. Kinetic for pseudo second order reaction of tea fiber

Time	k ₂	S.D
10	0.000075	0.000046
20	0.000034	
30	0.000015	
40	0.000006	

Table 9 Kinetic for first order of tea leaf

Time	k ₁	S.D
10	0.0013	0.00052
20	0.0005	
30	0.0002	
40	0.00008	

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Table 10. Kinetic for second order of tea leaves

Time	k_2	S.D
10	0.000045	0.0000018
20	0.000017	
30	0.000008	
40	0.000003	

Isotherm Studies

Table 11. The isotherm study of tea fiber and tea leaves.

adsorbent	Co	Ce	1/ce	LogCe	Qe	1/qe	LogQe	$\frac{ce}{qe}$	%R
Fiber	20	0.800	1.25	-0.1	0.960	1.04	-0.01	0.82	96.00
	30	0.800	1.25	-0.1	1.460	0.68	0.20	0.50	97.33
	40	0.500	2.0	-0.3	1.975	0.51	0.30	0.30	98.75
	50	0.300	3.30	-0.5	2.485	0.41	0.40	0.10	99.40
leaves	20	0.600	1.67	-0.2	0.970	1.03	-0.01	0.62	97.00
	30	0.400	2.50	-0.4	1.480	0.68	0.20	0.30	98.67
	40	0.300	3.30	-0.5	1.985	0.50	0.30	0.20	99.25
	50	0.100	10	-1	2.495	0.40	0.40	0.04	99.80

The affinity of biosorbent, surface properties, mechanism of sorption, can easily be computed by the adsorption isotherm. At equilibrium conditions for the uptake of iron (ii) ions by

tea leaves and tea fibre adsorbent, the sorption process in an aqueous solution decreases hence, the system was not suitable for description by the Freundlich isotherms.

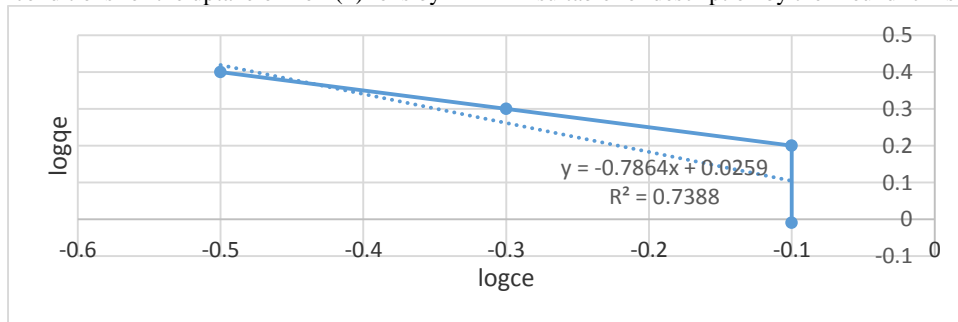


Figure 15. The linearized Freundlich biosorption isotherm of iron by tea fiber.

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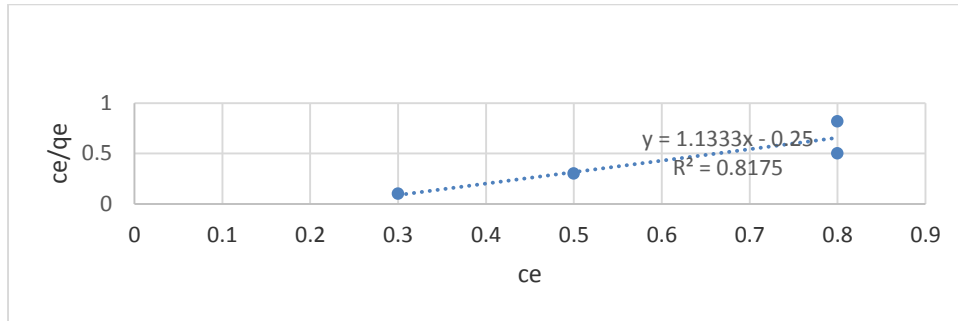


Figure 16 The linearized Langmuir biosorption isotherm of iron by tea fiber

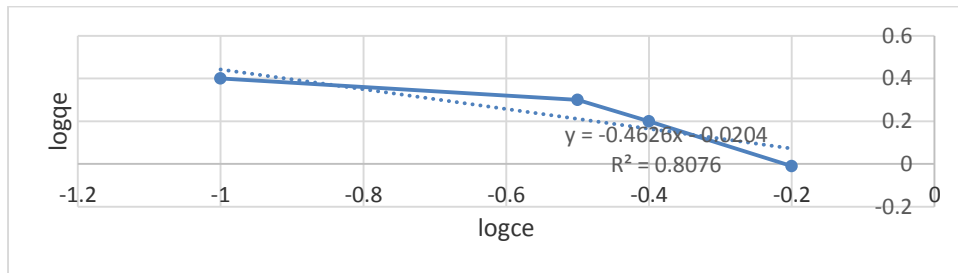


Figure 17. The linearized Freundlich biosorption isotherm of iron by tea leaves.

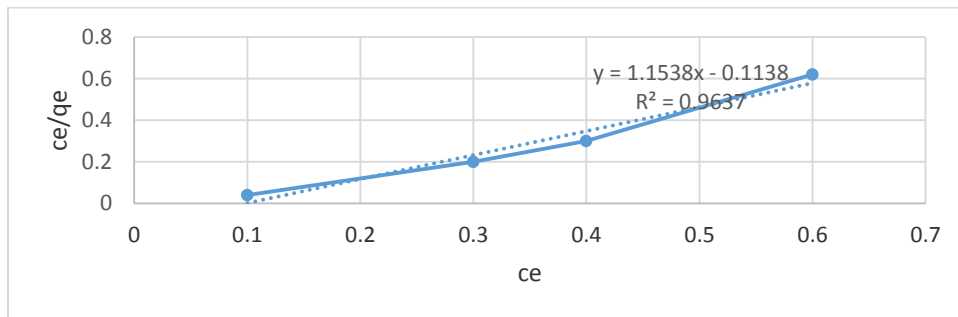


Figure 18. The linearized Langmuir biosorption isotherm of iron by tea leaves

Thermodynamics

Table 12 Thermodynamic parameters for fiber and leaves

adsorbent	Temp(k)	$\frac{1}{T \times 10^{-3}}$	Ce	Qe	Kc	Inkc	%R
Fiber	313	3.20	0.400	1.480	3.70	1.31	98.67
	323	3.10	0.200	1.485	4.95	1.59	99.00
	333	3.00	0.200	1.490	7.45	2.01	99.33
	343	2.90	0.100	1.495	14.95	2.70	99.67
Leaves	313	3.20	0.600	1.470	2.45	1.00	98.00
	323	3.10	0.500	1.475	2.95	1.08	98.33
	333	3.00	0.400	1.480	3.70	1.31	98.67
	343	2.90	0.200	1.490	7.45	2.00	99.33

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Table 9 and Figs 19 and 20 present the thermodynamic statement for the sorption of iron(ii)ions by tea leaves and tea fibre. For the tea leaves and fibre, the sorption's free energy change at 313 K, was -9550 and -6829 kJ mol⁻¹, respectively. This was justified by the information provided by the Gibbs free energy (ΔG^0 , k cal mol⁻¹), enthalpy (ΔH^0 , k cal mol⁻¹) and entropy (ΔS^0 , cal mol⁻¹ k⁻¹) changes during the sorption process which were computed at 313, 323, 333

and 343 K temperatures, as a result increase in temperature results to negative Gibbs free energy change (ΔG^0) as reported by Malakootian *et al.* (2008). The negative values indicate how spontaneous the adsorption process was. The negative values of standard enthalpy change (ΔH^0) for the intervals of temperatures were indicative of the exothermic nature of the adsorption process.

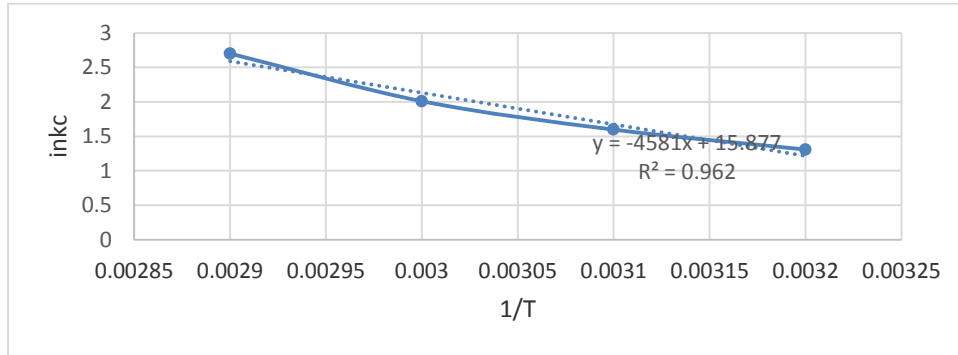


Figure 19. Plot of lnKc versus 1/T for tea fiber

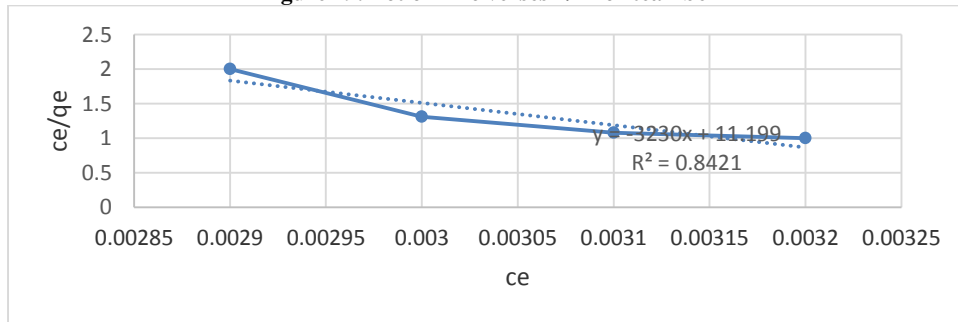


Figure 20 Plot of lnKc versus 1/T for tea leaves

Table 13. Thermodynamics representation

	Fiber				Leaves			
	ΔH (kJ/mol)	-4581	-4581	-4581	-4581	-3230	-3230	-3230
ΔS (kJ/mol)	15.877	15.877	15.877	15.877	11.499	11.499	11.499	11.499
Temp(k)	313	323	333	343	313	323	333	343
ΔG (kJ/mol)	-9550	-9709	-9868	-10026	-6829	-6944	-7059	-7174

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Determination of functional group using

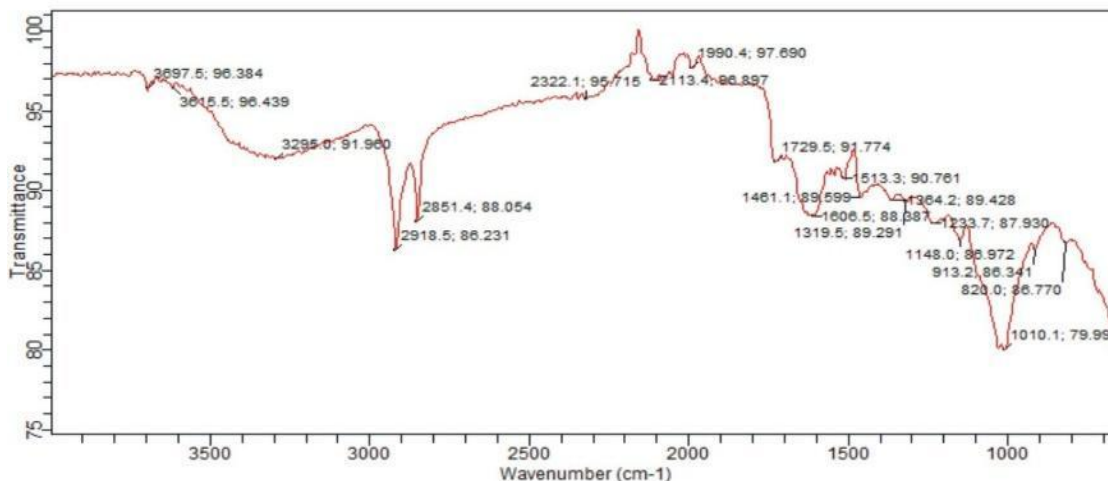


Figure 21 FTIR analysis for tea leaves

Table 14. Functional groups of tea leaf

Peaks	Bond type	Functional group
3697.5	N-H	Primary amine
3615.6	O-H	Carbohydrate; protein; Alcohol
2918.5	C-H	Alkane
2322.1	P-	Phosphine
1729.5	C=O	Aromatic ketone
1606.5	N-H	Primary amine
1461.1	-C=O	Inorganic carbonate
1364.2	C-N	Aromatic amine
1233.7	C-O	Carboxylic acid
1010.1	C-O	Primary alcohol

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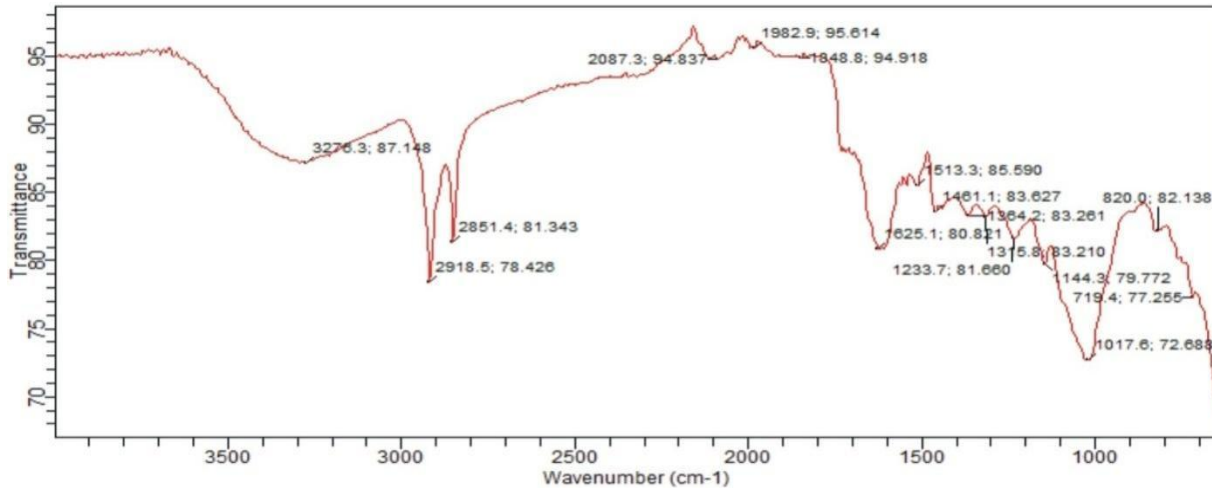


Figure 22 FTIR Analysis for tea fibre

Table 15. Functional groups for tea fiber

Peak wavelength	Bond type	Functional group
3276.2	O-H	Carbohydrate; protein; phenol
2918.5	C-H	Alkane
1625.1	-C=O	Amide band I
1513.1	-C=O	Carboxylic acid
1315.8	C-N	Amide band III
1144.2	C-O	Secondary alcohol
1017.6	C-O	Ether

The FT-IR spectrum provides information about the various functional groups that are present on the adsorbent. The sharp and high spectrum around 3448cm^{-1} are signals showing $-\text{OH}$ and $-\text{NH}_2$ functional groups whereas, lower bands such as 2910cm^{-1} , 1637cm^{-1} , provides information about C-H stretch of alkane and C=O stretch bands respectively while 1560cm^{-1} indicates $-\text{NH}$, $-\text{CN}$ and $-\text{NO}$ stretch. Comparing the spectra obtained for tea leaf and the tea fibres, it can be observed that from table 4.14 there is a presence of inorganic carbonate with peak wavelength of 1461.1cm^{-1} and primary amine with peak wavelength of 3697.5cm^{-1} in the tea leaf while there is an absence of these two groups in the tea fibres as presented in table 4.15 above. The absence of these two groups in the tea fibres is as a result of the reactions that they have undergone during the tea processing in the factory which leads to the loss of these two groups in the tea fibres.

Conclusion

This research looked at the removal of Fe (II) metal by tea leaves and tea fiber from a solution and found the adsorbent

to be effective for the sorption process. According to the findings, adsorption constraints such as initial concentration, contact time, adsorbent dosage, temperature, and pH of the solution all have a significant impact on the adsorbent's efficacy. The tests were carried out at pH levels ranging from 1 to 7 and for a maximum of 60 minutes. The disappearance of old spectral lines and the appearance of new ones after sorption, as shown by FTIR spectroscopy results, indicates effective adsorbate sorption by the adsorbent. The process demonstrates that the best fit used pseudo first order kinetics. Furthermore, the thermodynamic state of the system indicates that it was endothermic and spontaneous at 30 mg L^{-1} , with a high tendency for disorderliness at the interface. As a result, the study proposes tea leaves and tea fiber, which are widely available and inexpensive byproducts of tea processing, as effective biosorbents for iron removal from waste water.

Conflict of Interest: The authors declare no conflict of interest.

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