International Journal of Chemical Studies

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Adsorption behavior of Fe (II) ion from aqueous solution onto nano carbon

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Abstract
Gloriosa Superba Stem obtained from nearby Thiruvarur district, having the particle size (40-120 μm) was used as an adsorbent for the removal of Fe (II) ion from aqueous solution. The effect of various factors (temperature, adsorbent dose and Initial pH) on adsorption of Fe (II) on Gloriosa Superba was investigated. The effect of pH shows that the amount adsorbed increased with the increase of pH of solution. The equilibrium adsorption isotherms were analyzed by Langmuir and Freundlich equations. Both Langmuir and Freundlich models can describe the adsorption equilibrium but the Langmuir model shows better agreement. The amount adsorbed increased with the increase of temperature suggests the formation of dimer in the contact region. SEM micrographs and differential molar isosteric heat of adsorption (ΔH) calculated at different surface coverage, indicate that the surface is heterogeneous having energetically different adsorption sites. Values of n calculated from Freundlich plots indicate that adsorption of Fe (II) on Gloriosa Superba is spontaneous. At high surface coverage, the differential heat of adsorption versus surface coverage plot shows maximum value indicating the occurrence of structural rearrangement in the adsorbate. With the increase of adsorbent dose, amount adsorbed increased due to the increased surface area of adsorbent.

Keywords: Fe(II) ion, Activated Gloriosa Superba Nano Carbon (AGSNC), Adsorption models, Equilibrium.

1. Introduction

Water is the main component for living organisms, and the increase in water pollution as a result of progress in the industrial technologies, has been reduced using many methods to treat the wastewater [1]. The choice of suitable methods is controlled by different factors such as the efficiency of removing the pollutant materials, the availability of the used chemicals and the chemistry of the contaminated materials beside the process cost [2]. It is well–known that the pollutants in wastewater discharge from industrial effluents, sewage, sludge, pesticides, and fertilizers. The composition of the contaminated water depends on the source of the pollutant, the chemical composition of the original water whether it is surface or underground water and then the chemical reaction with the soil. For example, groundwater contains one or more contaminants like iron, manganese, ammonium, methane and natural organic matter, e.g., humic acid. Hence, before using this water supply for agro-irrigation purposes, these contaminants should be removed or reduced to the acceptable levels. Iron and manganese, which are usually present in the groundwater as divalent cations, considered to be contaminants mainly due to their organoleptic properties. The maximum recommended levels of Fe in drinking water are 0.3 mg/L, respectively. There are various methods for removing Fe (II) cations from the wastewater including ion-exchange method [3], oxidation by oxidizing agents such as chlorine and potassium permanganate [4], activated carbon and/or other filtering materials [5-7], supercritical fluid extraction (Andersen and Bruno, 2003), bioremediation [8], and treatment with limestone [9]. Some of these methods are simple and economic while the others are complicated and expensive. In oxidation treatment, oxygen, chlorine or potassium permanganate (KMnO4), is generally used for Fe (II) oxidation. Adsorption using activated carbon is an effective technique to remove heavy metals from wastewater [10] that is due to that activated carbon has a pore size distribution which controls its adsorption capacity, a chemical structure that influences its interaction with polar and non-polar adsorbate, and active sites which determine the type of chemical reactions with other molecules [11].

However, in developing countries such as India, traditional activated carbon remains an expensive material for heavy metal removal. Recently, many researchers have been published

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in the literature including preparation of activated carbons from various cheaper and alternative materials, e.g., agricultural by-products and biomass materials, using chemical activation with H_3PO_4 [12-14]. However, there is only limited research on the preparation of activated carbons from woody biomass such as sawdust for uptaking heavy metals such as Hg (II) from wastewaters [15, 16] reported that the removal of Fe, Mn and Cu ions from acid mine drainage (AMD) by precipitation with NaOH depends on the pH value besides the oxidation state of the removed cations. On the other hand, various authors found that the removal of iron and other heavy metals by activated carbon depends on the nature of carbon (porosity, surface area, oxygen functional groups, etc.). Within the frame of this policy, the present paper narrates the investigation of Fe (II) ions removal from aqueous solution using adsorption methods in order to determine the optimum pH for the effective removal. The adsorption was carried out using an activated carbon obtained from Gloriosa Superba Stem. The adsorption data was analyzed by using Langmuir and Freundlich isotherm models. Overall, this study was also intended to determine the efficiency and the optimum conditions in adsorption processes for removal of iron cations.

2. Materials and Methods
2.1. Adsorbent
The natural plant material Gloriosa Superba, used in the present investigations was collected from Thiruvarur district the Stem were washed with distilled water several times to remove the dirt and dust and was subsequently dried in a hot air oven at 110 ^{0}C. Afterward, carbonization of the Gloriosa Superba was carried out at 200 ^{0}C for 6 hour in a muffle furnace. A linsang nitrogen (purity 99.99%) flow of 150ml/min was maintained throughout the process of carbonization primary carbon was obtained on carbonization, which was afterward mixed with Zinc chloride. Zinc chloride acts as a catalyst in the process. The primary carbon was activated at 1100 ºC for 6 hrs under optimized conditions to obtain activated nano carbon. The activated carbon was thereafter looked to room temperature in an insert atmosphere of nitrogen and washed with hot distilled water and 0.5 N Hydrochloric and until the pH of the material reached 7.0 the activated carbon was also dried in a hot air oven at 110 ^{0}C, ground and sieved to obtain the desired particular size (150 µm) and stored in desiccators for further use.

2.2. Chemicals
All chemicals used of high purity commercially available Analar grade purchased from scientific equipment company trichy. Iron solution was prepared from $FeSO_4.7 H_2O$ (2.489 g in 500 ml distilled water equivalent to one gram/liter). All experimental solutions were prepared by diluting the stock solution to the required concentration. The pH of each experimental solution was adjusted to the required initial pH value using dilute HCl (or) NaOH before mixing the adsorbent. The concentration of residual Fe(II) was determined with atomic absorption spectrophotometer (Perkin Elemer 2380).

2.3. Batch experiments
The effect of various parameters on the removal of Fe(II) onto AGSNC was studied batch adsorption experiments were conducted at (30-60 °C). For each experimental run, 50 ml of iron solution of known initial concentration and pH were taken in a 250 ml plugged conical flask. A 25 mg adsorbent dose is added to the solution and mixture was shaken at constant agitation speed (200 rpm) sample were withdrawn at appropriate time intervals (10-60 min) and the adsorbent was separated by filtration. The residual solutions were analyzed to determine the Fe(II) concentration.
The effect of dosage of adsorbent on the removal of Fe(II) was measured by contacting 50 ml of 50 mg/L of Fe(II) solution with 25 mg of AGSNC till equilibrium was attained.
Adsorption equilibrium isotherm is studied using 25 mg of AGSNC dosage per 50 ml of Fe(II) solution. The initial concentration were ranged from (25 to 125 mg/L) in all sets of experiments. The plugged conical flask was shaken at a speed of 200 rpm for 60 minutes. Then the solution was separated from the mixture and analyzed for Fe(II) concentration. The adsorption capacity was calculated by using a mass equilibrium equation as follows:

$$q_e = (C_0 - C_e) V/M \qquad (1)$$

Where C_0 and C_e being the initial iron concentration (mg/L) and equilibrium concentration, respectively V is the experimental volume of Fe(II) solution expressed in liters [L] and M is the adsorbent mass expressed in grams [g]. The Fe(II) ions percentage can be calculated as follows:

$$\%Removal = (C_0 - C_t) \times 100/C_0 \qquad (2)$$

The effect of pH on the rate of adsorption was investigated using iron concentration of 25 mg/L constant AGSNC dosage. The pH values were adjusted with dilute HCl and NaOH solution. The adsorbent − adsorbate mixture was shaken at room temperature using agitation speed (200 rpm) for 60 minutes. Then the concentration of Iron in solution was determined.

3. Result and Discussion
3.1 Characterization.
The different chemical constituents of activated Gloriosa Superba are given in Table 1 along with some other characteristics. X-ray spectra of both adsorbents do not show any peak indicating the amorphous nature of activated Gloriosa Superba.

Table 1: Characteristics of the Adsorbent

Properties	AGSNC
Particle size (mm)	0.00011
Density (g/cc)	0.2235
Moisture content (%)	0.2157
Loss in ignition (%)	0.0217
pH of aqueous solution	6.200

3.2 Adsorption studies
Batch experiments were performed to investigate the adsorption process of Fe (II) by the AGSNC. For each experimental run, 50 mL of Fe (II) solution of known concentration, initial pH, ionic strength and the amount of the

AGSNC were taken in a 250-mL stoppered conical flask. This mixture was agitated in a temperature-controlled shaking water bath at a constant speed of 120 rpm/min and certain temperatures. For adsorption equilibrium studies, Fe (II) solutions of different concentrations were contacted with a certain amount of AGSNC under certain conditions for an hr insuring the equilibrium was achieved. The residual Fe (II) concentration was then measured and the amount of Fe (II) adsorbed onto AGSNC was calculated from mass balance. Effects of contact time, adsorbent dosage, initial Fe (II) concentration, initial solution pH, ionic strength and temperature) on Fe (II) adsorption by AGSNC were investigated. Adsorption kinetics was determined by analyzing adsorptive uptake of Fe (II) from aqueous solution at different time intervals [18]. The amount of Fe (II) adsorbed at time t, q_t (mg/g), was calculated using mass balance equation.

3.3 Effect of Contact Time
Figure 1 shows the effect of contact time on the adsorption of Fe(II) ions solution using AGSNC. The concentrations of Fe(II) ions in solution were varied from 25 mg/L to 125 mg/L and batch adsorption was carried out with 25mg of AGSNC. The percentage of Fe(II) ions adsorbed increased with time until equilibrium was reached for each concentration. It is therefore evident from Fig 1 that at low concentration ranges the percent adsorption is high because of the availability of more reactive sites. At higher concentration of Fe (II) ion more and more surface sites are covered, the capacity of the adsorbent get exhausted due to non-availability of active surface sites. This leads to a fall in the percentage of Fe (II) ion adsorbed at higher concentration [19]. It was observed that the percentage adsorption of Fe(II) ion rapidly reached equilibrium at 30 minutes of contact for 25 mg/L concentration, it increased to 100% implied that Fe(II) (Fe^{2+}) ion was completely removed from aqueous solution at this concentration.
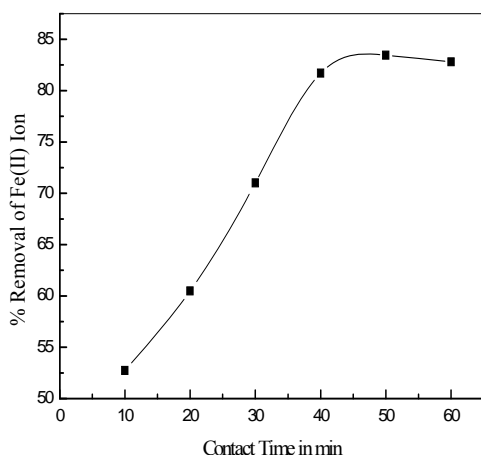

Fig.1-Effect of Contact Time on the Removal of Fe(II) ion
[Fe(II)]=50 mg/L; adsorbent dose=25mg/50ml; pH-6.2; Temp 30^{0}C

3.4 Effect of Initial Concentration
The effect of initial concentration of Fe(II) ions on adsorption of Fe(II) ions using AGSNC. Adsorption of irons (II) ions in solution increase significantly with reduction in the initial concentration of Fe(II) ions in solution. The initial concentration of adsorbate varied from 25mg/L to 125mg/L. The rate of adsorption decreased from 91%-55% as the concentration of Fe(II) ions increased from 25mg/L to 125mg/L within 30 min of adsorption. This was expected and

shows that there more reactive sites on the pore of Gloriosa Superba activated carbon.

3.5 Effect of Dosage
Fe(II) ions in aqueous solution of known concentration was adsorbed using different carbon dosage of activated Gloriosa Superba ranging from 25 mg-125 mg in 50 ml of stock solution of Fe(II) ions. The effect of carbon dosage on the adsorption of Fe(II) ions using AGSNC is presented in Fig 2. There was significant increase in the adsorption of Fe(II) ions in solution as carbon dosage increased within adsorption time of 30 min reported similar findings during the removal of Fe (II) ion adsorption by AGSNC. This is due to the increased availability of active adsorption sites arising due to the increase in effective surface area resulting from the increases in dose of adsorbent or due to conglomeration of the adsorbent. Increasing the adsorbent dosage further, it was found that the optimum uptake of Fe(II) ions requires about 25 mg of AGSNC to adsorb 100% Fe(II) ions in aqueous stock Fe(II) solution [14].
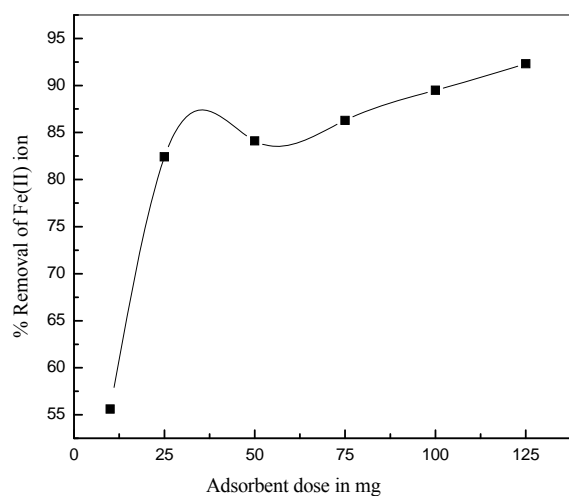

Fig.2-Effect of adsorbent dose on the removal of Fe(II) Ion
[Fe(II)]=50mg/L: Contact time=50 min: pH=6.2: Temp 30^{0}C

3.6 Effect of Particle Size
Effect of particle size of activated carbon produced from waste Gloriosa Superba on the batch adsorption of Fe(II) ions in aqueous solution. The adsorption of Fe(II) ions increased with reduction in particle size [19]. The shape reduction also revealed that particle size of AGSNC has significant effect on the adsorption of Fe(II) ions in aqueous solution for batch process. Smaller particle size ($\leq$ 150 μm) adsorbed the highest amount of Fe(II) ions within 30 mins of adsorption, hence for effective adsorption of Fe(II) ions in aqueous solution using Gloriosa Superba.

3.7 Effect of pH
Effect of pH on adsorption of Fe (II) ion: The pH of the wastewater is one of the imperative factors governing the adsorption of the Fe (II) ions. The effect of pH was studied from a range of 2 to 6 under the precise conditions (at optimum contact time of 60 min, 200 rpm shaking speed, with 25mg of the adsorbents used, and at a room temperature of 30 ^{o}C). From Figure-3, with AGSNC used as adsorbent, it was observed that with increase in the pH (2.0-6.2) of the wastewater, the percentage removal of iron ((II)) ions increased up to the pH 6.2 as shown above. At pH 6.2, maximum removal was obtained for Fe (II) ions, with 91% removal of Fe (II). The increase in percentage removal of the

Fe (II) ions may be explained by the fact that at higher pH the adsorbent surface is deprotonated and negatively charge; hence attraction between the positively Fe(II) cations occurred [20].
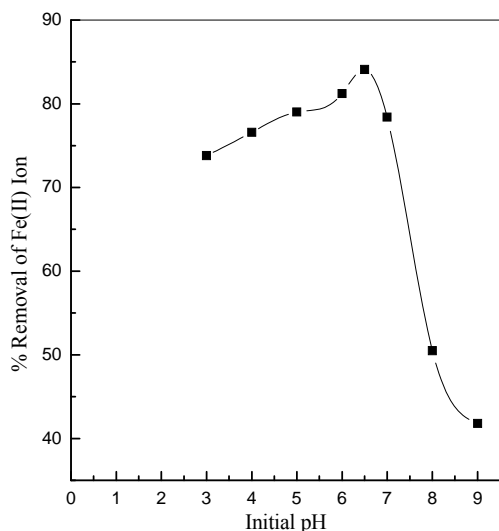

Fig.3-Effect of Initial pH on the removal of Fe(II) Ion
[Fe(II)]=50mg/L: Contact time=50 min: dose=25mg/50ml

3.8 Adsorption Models
The adsorption equilibrium data were further analyzed into two well-known isotherm models via Freundlich and Langmuir models.

3.8.1 Freundlich model
The Freundlich model which is an indicative of surface heterogeneity of the adsorbent is described by the following equation.

$$\text{Log } q_e = \log k_f + 1/n + \log Ce \qquad (9)$$

Where K_f and $1/n$ are Freundlich constants associated with adsorption capacity and adsorption intensity respectively, The Freundlich plots between $\log q_e$ and $\log C_e$ for the adsorption of Fe(II) were drawn. It was found that correlation efficient values were less than 0.99 at both the temperature studied indicating that Freundlich model was not applicable to the present study.

3.8.2 Langmuir model
The adsorption isotherm was also fitted to Langmuir model. The Langmuir equation which is valid for monolayer adsorption on to a surface is given below.

$$1/q_e = 1/q_m + 1/q_{mb}C_e \qquad (10)$$

Where q_e (mgg^{-1}) is the amount adsorbed at the equilibrium concentration C_e (mol L^{-1}), q_m (mgg^{-1}) is the Langmuir constant representing the maximum monolayer adsorption capacity and b (L mol^{-1}) is the Langmuir constant related to energy of adsorption. The plots $1/q_e$ as a function of $1/C_e$ for the adsorption of Fe (II) was found linear. Suggesting the applicability if Langmuir model in the present adsorption system. The correction coefficient ($R^2 = 0.9911$ and 0.9894 at 30 & 60 °C respectively for Langmuir model) confirm good agreement between both theoretical models and our experimental results the values of the monolayer capacity (q_m) and equilibrium constant (b) have been evaluated from the intercept and slope of these plots and given in Table 3. It is adsorbent for the Fe (II) is comparable to the maximum adsorption obtained from the adsorption isotherms. These facts suggest that Fe (II) is adsorbed in the form of monolayer coverage on the surface of the prepared adsorbent [21].

Satisfactory fitting of the Langmuir model to the adsorption of Fe (II) on AGSNC.

3.9 Kinetics study
The Kinetic adsorption data were evaluated to understand the dynamics of the adsorption reaction in terms of the order of the rate constant batch experiments were conducted to explore the rate of Fe (II) adsorption by Gloriosa Superba as described in adsorption isotherms section at pH 6.2. Three Kinetic models were applied to the adsorption Kinetic data in order to investigate the behavior of adsorption process of Fe (II) onto the adsorbents. These models include the pseudo first order Kinetics (reversible or irreversible), the pseudo – Second - order and the intra particle diffusion models the linear form of reversible pseudo – first – order model can be formulated as:

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

Where q_e (mol/g) and q_t (mole/g) are the amount of Fe (II) adsorbed at equilibrium and at time t, respectively and k_1 (min^{-1}) is the rate constant k_1 values were evaluated from the linear regression of ln (q_e-q_t) versus data. Linear from of irreversible pseudo first order model can be formulated as:

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

Where C_o (mg/l) is the initial concentration of Fe (II) and C_t (mg/l) is equilibrium concentration of Fe (II) at time 't' respectively, and k g min^{-1} is the rate constant Evaluation of data has been done using linear plot of ln (C_o/C_t) versus time. The Linear form of pseudo – Second – order equation can be formulated us.

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

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

3.10 The Elovich equation and intra-particle diffusion model
The Elovich model equation is generally expressed as

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

Where; α is the initial adsorption rate (mg g^{-1} min^{-1}) and β is the desorption constant (g/mg) during any one experiment. To simplify the Elovich equation. [24] assumed $\alpha\beta t \gg t$ and by applying boundary conditions $q_t = 0$ at t= 0 and $q_t = q_t$ at t = t Eq.(10) becomes:

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

If Fe (II) ions adsorption fits with the Elovich model, a plot of q_t vs. in (t) should yield a linear relationship with a slope of $(1/\beta)$ and an intercept of $(1/\beta) \ln (\alpha\beta)$. The Elovich model parameters α, β, and correlation coefficient (γ) are summarized in table 6. The experimental data such as the initial adsorption rate (α) adsorption constant (β) and the correlation co-efficient (γ) calculated from this model indicates that the initial adsorption (α) increases with temperature similar to that of initial adsorption rate (h) in pseudo-second–order kinetics models [22]. This may be due to increase the pore or active site on the AGSNC adsorbent.

For adsorption of Fe (II) on to AGSNC the obtained results represent more conformity to pseudo-second order model (R^2 =0.95), the initial adsorption rate $k_2 q_e^2$ for AGSNC. Kinetic

data for the adsorption of Fe (II) were also analyzed according to intra-particle diffusion model achieve can be formulated as [25].

$$Q_t = k_{pt} \, 0.5 \tag{12}$$

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

3.11 Adsorption Thermodynamics

The thermodynamic parameters for the adsorption of Fe (II) ions by AGSNC were determined using the following equations:

$$K_D = q_e/C_e \tag{13}$$
$$\Delta G^o = - RT \ln K_D \tag{14}$$
$$\ln K_D = (\Delta S^o/R) - (\Delta H^o/RT) \tag{15}$$

Where K_D is the distribution coefficient for the adsorption in g/L, ΔG^o is the Gibbs free energy in J/mol,
R is the universal gas constant in J/mol K, T is the absolute temperature in K, ΔS^o is the entropy change in J/mol K and ΔH^o is the enthalpy change in kJ/mol [23]. The values of Gibbs free energy (ΔG^o) for various temperatures were calculated from the experimental data. The values of enthalpy change (ΔH^o) and entropy change (ΔS^o) were estimated from the slope and intercept of the plot of ln K_D Vs 1/T. The estimated thermodynamic parameters were tabulated and shown in table 5. But the negative values of Gibbs free energy change (ΔG^o) obtained for the adsorption of Fe (II) ions by AGSNC at

various temperatures had shown the spontaneous nature of the adsorption process.

The positive values of enthalpy change (ΔH°) obtained for the adsorption of Fe (II) ions by AGSNC at various temperatures indicated that the adsorption reactions were endothermic. The positive values of entropy change (ΔS°) for the adsorption of Fe (II) ions by AGSNC at various temperatures showed the increased randomness at solid liquid interphase during the sorption processes of Fe (II) ions on the adsorbent AGSNC. This is a direct consequence of (i) opening up of structure of adsorbent beads (ii) enhancing the mobility and extent of penetration within the adsorbent beads and (iii) overcoming the activation energy barrier and enhancing the rate of intra-particle diffusion [25].

The adsorption of Fe (II) ions by AGSNC slightly increased when temperature was raised up to 60 ºC. It might be due to the generation of new active sites on the adsorbent surface and also due to the increased rate of pore diffusion. But when the temperature was further raised, adsorption processes had decreased largely. It showed that the adsorption processes of Fe (II) ions by AGSNC were exothermic reactions and physical in nature which involved the weak forces of attraction between the sorbate-sorbent molecules.

3.12. Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the Fe (II) ions. If the adsorbed Fe (II) ions can be desorbed using neutral pH water, then the attachment of the Fe (II) ion of the adsorbent is by weak bonds. The effect of various reagents used for desorption studies. The results indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 91% removal of adsorbed Fe (II) ion. The reversibility of adsorbed Fe (II) ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of Fe (II) ion by mineral acids and alkaline medium indicates that the Fe (II) ion was adsorbed onto the AGSNC through physisorption as well as by chemisorptions mechanisms.

Table 2: Equilibrium Parameters For The Adsorption Of Fe(Ii) Ion Onto Agsnc

M_0	Ce (Mg / L)				Qe (Mg / L)				Removal %			
	30 ºC	40 ºC	50 ºC	60 ºC	30 ºC	40 ºC	50 ºC	60 ºC	30 ºC	40 ºC	50 ºC	60 ºC
25	2.1595	1.9364	1.7459	1.6277	45.681	46.127	46.508	46.744	91.362	92.254	93.016	93.489
50	8.5128	7.5685	6.2961	5.3842	82.974	84.863	87.407	89.231	82.974	84.863	87.407	89.231
75	18.480	16.375	14.354	12.569	113.04	117.24	121.29	124.86	75.360	78.166	80.861	83.240
100	35.516	32.848	14.354	27.262	128.96	134.30	171.29	145.47	64.483	67.151	85.645	72.738
125	55.164	51.787	30.044	45.312	139.67	146.42	189.91	159.37	55.869	58.570	75.964	63.750

Table: 3: Langmuir And Freundlich Isotherm Parameter For The Adsorption Of Fe(Ii) Ion Onto Agsnc

Temp (ºC)	Langmuir Parameters		Freundlich Parameters	
	Q_m	b	K_f	n
30 ºC	154.41	0.1560	37.102	2.8538
40 ºC	161.76	0.1663	39.017	2.8066
50 ºC	245.30	0.1031	35.216	1.9554
60 ºC	175.53	0.1999	43.592	2.7237

Table: 4: Dimensionless Seperation Factor (R_l) For The Adsorption of Fe (Ii) Ion Onto Agsnc

(C_i)	Temperature °C			
	30 ºC	40 ºC	50 ºC	60 ºC
25	0.1136	0.1074	0.1624	0.0910
50	0.0602	0.0567	0.0884	0.0476
75	0.0410	0.0385	0.0607	0.0323
100	0.0311	0.0292	0.0462	0.0244
125	0.0250	0.0235	0.0373	0.0196

Table 5: Thermodynamic Parameter For The Adsorption Of Fe(Ii) Ion Onto Agsnc

(C₀)	ΔG°				ΔH°	ΔS°
	30 ºC	**40 ºC**	**50 ºC**	**60 ºC**		
25	-5941.8	-6446.9	-6953.1	-7376.5	8.6486	48.202
50	-3989.8	-4486.1	-5203.0	-5854.4	15.121	62.907
75	-2816.2	-3318.9	-3869.7	-4437.4	13.582	54.063
100	-1502.5	-1860.8	-4796.6	-2717.0	19.135	68.725
125	-594.10	-901.00	-3090.2	-1563.0	15.369	53.165

Table 6: The Kinetic Parameters for the Adsorption of Fe (Ii) Ion Onto Agsnc

C₀	Temp °C	Pseudo second order				Elovich model			Intraparticle diffusion		
		qe	**k₂**	**γ**	**h**	**α**	**β**	**γ**	**Kid**	**γ**	**C**
25	30	51.769	0.0021	0.9834	5.5878	31.106	0.1208	0.9811	0.2108	0.9907	1.5791
	40	51.792	0.0022	0.9855	5.9377	39.963	0.1265	0.9831	0.1980	0.9928	1.6050
	50	51.779	0.0024	0.9826	6.3631	52.326	0.1324	0.9803	0.1861	0.9899	1.6293
	60	52.127	0.0023	0.9837	6.3529	49.932	0.1302	0.9814	0.1885	0.9910	1.6278
50	30	94.473	0.0011	0.9828	9.6456	47.791	0.0642	0.9805	0.2203	0.9901	1.5192
	40	96.191	0.0011	0.9839	10.107	55.994	0.0650	0.9816	0.2118	0.9912	1.5432
	50	98.151	0.0012	0.9830	11.268	73.765	0.0663	0.9807	0.1995	0.9903	1.5792
	60	100.30	0.0012	0.9851	11.646	74.923	0.0646	0.9827	0.2003	0.9924	1.5883
75	30	131.47	0.0007	0.9832	11.547	45.042	0.0431	0.9809	0.2448	0.9905	1.4331
	40	134.60	0.0007	0.9825	12.950	57.755	0.0438	0.9802	0.2301	0.9898	1.4757
	50	138.54	0.0007	0.9825	14.347	71.471	0.0439	0.9802	0.2195	0.9898	1.5120
	60	141.12	0.0006	0.9844	12.246	84.156	0.0468	0.9820	0.2013	0.9917	1.5319
100	30	156.36	0.0004	0.9827	10.667	30.079	0.0325	0.9804	0.2950	0.9900	1.2752
	40	160.71	0.0005	0.9838	11.745	35.848	0.0325	0.9815	0.2799	0.9911	1.3192
	50	165.45	0.0005	0.9849	13.008	43.231	0.0326	0.9825	0.2659	0.9922	1.3625
	60	169.41	0.0005	0.9840	15.098	57.375	0.0332	0.9817	0.2468	0.9913	1.4166
125	30	177.98	0.0003	0.9863	9.548	22.302	0.0263	0.9840	0.3481	0.9937	1.1179
	40	184.07	0.0003	0.9864	10.401	25.196	0.0259	0.9841	0.3354	0.9938	1.1602
	50	192.71	0.0003	0.9851	10.794	26.298	0.0248	0.9827	0.3347	0.9924	1.1799
	60	194.97	0.0003	0.9857	12.607	33.306	0.0254	0.9834	0.3090	0.9931	1.2452

4. Conclusion

Kinetics of batch adsorption of Fe(II) ions from aqueous solution using activated carbon from waste Gloriosa Superba has been investigated. The amount of Fe(II) ions adsorbed was found to vary significantly with process parameters such as particle size, carbon dosage, initial concentration of adsorbate and contact time. The adsorption process follows Langmuir and Freundlich isotherms but a better sorption fit using Langmuir isotherm model was obtained indicating a monolayer formation over a surface of the material. The monolayer saturation capacity of 154.41 mg of Fe(II) ions adsorbed per g of AGSNC was obtained and found to be higher than monolayer saturation capacity of other adsorbent used for Fe(II) ions adsorption. Adsorption kinetics was modeled using the pseudo first order, pseudo second order kinetic equations, and intra-particle diffusion models. Sorption kinetics showed good agreement of the experimental data the pseudo second order kinetic reaction is the rate controlling step with some intra particle diffusion taking place.

The high adsorption intensity of AGSNC and its affinity for Fe(II) ions can help solve many adsorption challenges in the industry and in water purification processes.

5. Acknowledgement

6. Reference

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