

CHAPTER V

5.1 ADSORPTION STUDIES MALACHITE GREEN DYE

5.1.1 Effect of contact time and initial MG dye concentration

The experimental results of adsorptions MG dye at various concentrations from 50 to 250 mg L⁻¹ with contact time are shown in representative Figure 5.1. The equilibrium data's collected in table 5.1 reveal that, percentage adsorption decreased with increase in initial dye concentration, but the actual amount of dye adsorbed per unit mass of carbon increased with increase in dye concentration. It means that the adsorption is highly depending on initial concentration of dye. It is because of that lower concentration, the ratio of the initial number of dye molecules to the available surface area is low subsequently the fractional adsorption becomes independent of initial concentration. However, at high concentration the available sites of adsorption become fewer and hence the percentage removal of dye is depending upon initial concentration [211]. Equilibrium has been established at 50 minutes for all concentrations. Figure 5.1 reveals that the curves are single, smooth, and continuous, leading to saturation, suggesting the possible monolayer coverage of the dyes on the carbon surface.

5.1.2 Effect of dosage

The adsorption of the Malachite green dye on AGSNC was studied by varying the nano carbon concentration (50-250 mg/50ml) for 50 mg L⁻¹ of dye concentration. The percentage adsorption increased with increase in the adsorbent concentration (Figure 5.2). This was attributed to increased adsorbent surface area and availability of more adsorption

sites. Hence the entire studies were carried out with the adsorbent dose 25mg of adsorbent/ 50 ml of the adsorbate solution [212].

5.1.3 Effect of pH

One of the most important parameters controlling the adsorption process is pH. The effect of pH of the solution on the adsorption of MG dye on AGSNC was determined. The result is shown in Figure 5.3. The pH of the solution was controlled by the addition of HCl or NaOH. The uptake of MG dye at pH 7.5 was the minimum and a maximum uptake was obtained at pH 3.0-6.7. However, when the pH of the solution was increased (more than 7.5), the uptake of MG dye was increased. It appears that a change in pH of the solution results in the formation of different ionic species, and different AGSNC surface charge. As pH values are lower than 6.7, the MG dye can enter the pore structure. As a pH values are higher than 6.7, the zwitterions form of MG dye in water may increase the aggregation of MG dye to form a bigger molecular form (dimer) and become unable to enter the pore structure of the AGSNC surface [213].

5.1.4 Effect of the Ionic Strength

The effect of sodium chloride on the adsorption of MG dye on AGSNC shows that a low solution concentration NaCl had little influence on the adsorption capacity. At higher ionic strength the adsorption of MG dye will be increased due to the partial neutralization of the positive charge on the AGSNC surface and a consequent compression of the electrical double layer by the chloride ions [214, 237]. The chloride ion can also enhance adsorption of MG dye onto AGSNC by pairing of their charges and hence reducing the repulsion between the MG dye molecules adsorbed on the surface. This initiates AGSNC to adsorb more of positive MG dye.

5.1.5 Theory of Adsorption isotherm

To quantify the sorption capacity of the absorbent for the removal of MG dyes, the most commonly used isotherm, namely Freundlich and Langmuir have been adopted.

5.1.5.1 Freundlich isotherm

The value of K_f and n are calculated from the intercept and slope of the plot of $\log q_e$ Vs $\log C_e$ respectively (Figure 5.3a). The constant K_f and 'n' values are given in table 5.2. In general K_f value increases the adsorption capacity for a given adsorbate increases [195]. The magnitude of the exponent $1/n$ gives an indication of the favorability of adsorption. The value of $n > 1$ represents favorable adsorption condition. The obtained value of $1/n$ lying in the range of 1 to 10 confirms the favorable condition for MG dye adsorption by AGSNC. This was further supported by Langmuir isotherm.

5.1.5.2 Langmuir isotherm

The Langmuir isotherm model [189,196] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. Q_m and 'b' are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the amount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption efficiency of the adsorbent and 'b' (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption) The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e) shows that the adsorption obeys the Langmuir model (Figure 5.3b). The Langmuir constant Q_m and 'b' were determined from the slope and intercept of the plot and are presented in table 7.2 shows higher affinity of AGSNC towards MG dye. In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm

can be expressed in terms of dimensionless constant separation factor R_L [196]. The obtained R_L values were in between 0 to 1 indicates favorable adsorption of MG dye for all initial concentration (C_o) and temperatures studied. The calculated R_L values were given in table 5.3.

5.6 Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0) and standard entropy change (ΔS^0) and these were calculated. The thermodynamic treatment of the sorption data indicates that ΔG^0 values were negative at all temperatures. From the results, it could be made out that physisorption was much more favorable for the adsorption of MG dye. The positive values of ΔH^0 show the endothermic nature of adsorption and they govern the possibility of physical adsorption. In the case of physical adsorption, while increasing the temperature of the system, the extent of dye adsorption increases, this rules out the possibility of chemisorptions. The low ΔH^0 value that depicts MG dye is physisorbed onto adsorbent AGSNC. The negative values of ΔG^0 (table 5.4) show the adsorption is highly favorable and spontaneous. The positive value of ΔS^0 (table 5.4) show the increased disorder and randomness at the solid solution interface of MG dyes with AGSNC adsorbent [188, 201].

5.7 Adsorption kinetics

The study of adsorption dynamics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of MG dyes adsorption on the AGSNC were analyzed using pseudo second-order

[198, 236] Elovich [129, 199] and intra-particle diffusion [200, 235] kinetic models. The conformity between experimental data and the model predicted values was expressed by the correlation coefficient (γ), (γ values close or equal to 1). The relatively high correlation coefficient (γ) value indicates that the model which successfully describes the kinetics of MG dyes adsorption on AGSNC adsorbent.

The pseudo-second- order rate constants k_2 the calculated 'h' values and the correlation coefficients (γ). The Elovich model parameters α , β and correlation coefficient (γ) are also summarized in table 5.5. The slope of the plot of qt Vs $t^{1/2}$ gives the value. The obtained intra -particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicates the fitness of this model. The intercept value indicates that the curve is not passing through the origin. So the intra-particle diffusion is not only rate controlling step. The intra-particle parameters are also summarized in table 5.5.

The above studies says that all above models successfully describe the kinetics of MG dyes adsorption on AGSNC adsorbent and it also gives the thickness of MG layer on AGSNC by intra-particle diffusion.

5.8 Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the MG dye. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because more than 70 % removal of adsorbed dye could be obtained. The reversibility of adsorbed dye in mineral acid is in agreement with the pH dependent results obtained. The desorption of

dye by mineral acids medium indicates that the MG dyes were adsorbed onto AGSNC through physisorption [202, 234].

5.9 Evidence of Adsorption

The FT-IR spectra of the raw AGSNC and after adsorption of dyes were shown respectively in Figure 5.4a and 5.4b. From the peaks, It could be seen that the slight reduction of stretching vibration adsorption bands. This one clearly indicates that the adsorption of MG dyes on the adsorbent by physical forces not by chemical combination. The XRD diagrams of AGSNC nano carbon and MG dyes adsorbed carbon was shown in Figure 5.5a and 5.5b. The intense main peak shows the presence of highly organized crystalline structure of raw AGSNC nano carbon, after the adsorption of MG dyes, the intensity of the highly organized peaks was slightly diminished. This was attributed to the adsorption of MG dyes on the upper layer of the crystalline structure of the nano carbon surface by means of physisorption.

TABLE: 5.1. EQUILIBRIUM PARAMETERS FOR ADSORPTION OF MG DYE ON AGSNC

M_0	Ce (Mg / L)				Qe (Mg / L)				Removal %			
	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C
50	2.6911	2.3383	2.0370	1.8501	94.618	95.323	95.926	96.300	94.618	95.323	95.926	96.300
100	12.740	11.246	9.2337	7.7914	174.52	177.51	181.53	184.42	87.260	88.754	90.766	92.209
150	28.504	25.175	21.978	19.156	242.99	249.65	256.04	261.69	80.998	83.217	85.348	87.230
200	55.448	51.229	21.978	42.394	289.10	297.54	356.04	315.21	72.276	74.386	89.011	78.803
250	86.524	81.183	46.794	70.942	326.95	337.63	406.41	358.12	65.391	67.527	81.282	71.623

TABLE: 5.2. LANGMUIR AND FREUNDLICH ISOTHERM PARAMETERS FOR MG DYE ON AGSNC

Temp. (°C)	Langmuir parameters		Freundlich parameters	
	Q_m	b	K_f	n
30°C	362.38	0.0851	68.146	2.7661
40°C	372.52	0.0946	72.600	2.7721
50°C	503.13	0.0753	67.486	2.1131
60°C	390.88	0.1234	82.551	2.7709

TABLE: 5.3. DIMENSIONLESS SEPERATION FACTOR (R_L) FOR MG DYE ON AGSNC

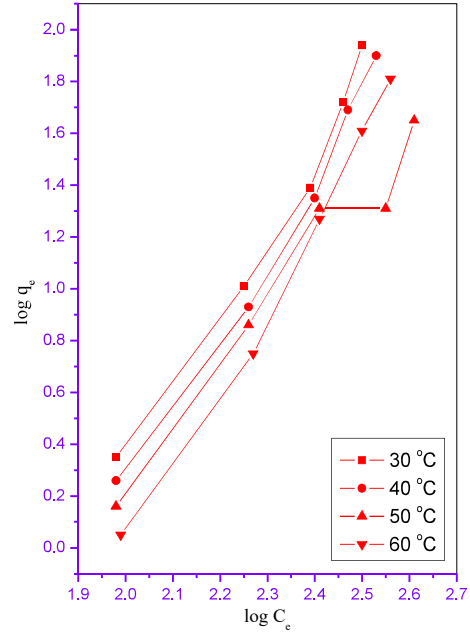
(C_i)	Temperature °C			
	30°C	40°C	50°C	60°C
50	0.1903	0.1745	0.2099	0.1394
100	0.1052	0.0956	0.1173	0.0749
150	0.0727	0.0658	0.0814	0.0512
200	0.0555	0.0502	0.0623	0.0389
250	0.0449	0.0406	0.0505	0.0314

TABLE: 5.4. THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF MG DYE ON AGSNC

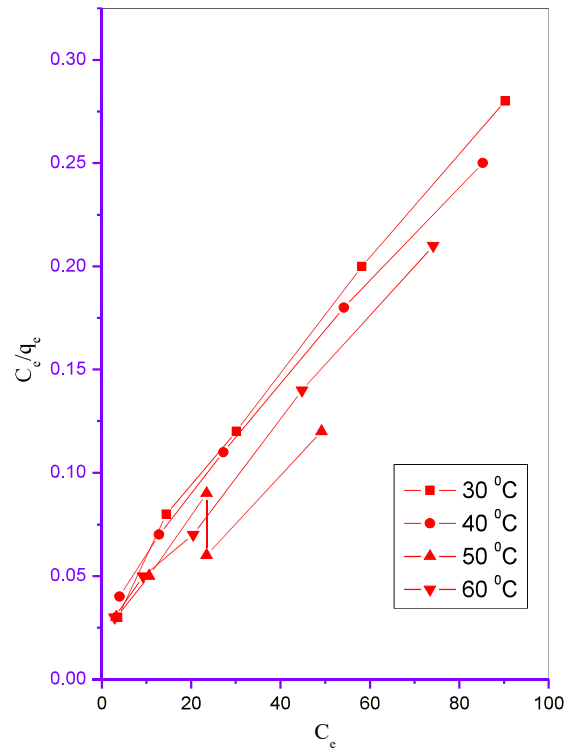
(C_0)	ΔG°				ΔH°	ΔS°
	30°C	40°C	50°C	60°C		
50	-7221.8	-7845.1	-8483.2	-9023.0	11.102	60.521
100	-4847.3	-5375.9	-6137.3	-6841.2	15.571	67.206
150	-3652.4	-4166.4	-4732.1	-5319.6	13.207	55.579
200	-2413.8	-2774.3	-5617.5	-3635.4	17.980	67.897
250	-1602.8	-1905.2	-3943.4	-2563.3	13.784	51.221

TABLE: 5.5. THE KINETIC PARAMETERS FOR ADSORPTION OF MG DYE ON AGSNC

C_0	Temp °C	Pseudo second order				Elovich model			Intraparticle diffusion		
		q_e	k_2	γ	h	α	β	γ	K_{id}	γ	C
50	30	103.17	0.0015	0.9747	16.198	271.75	0.0764	0.9817	0.1548	0.9887	1.6953
	40	103.34	0.0016	0.9768	17.063	378.27	0.0800	0.9838	0.1460	0.9908	1.7132
	50	103.45	0.0017	0.9740	18.141	538.38	0.0837	0.9809	0.1379	0.9879	1.7302
	60	103.97	0.0017	0.9750	18.075	498.11	0.0823	0.9820	0.1398	0.9890	1.7289
100	30	190.45	0.0008	0.9741	29.041	438.53	0.0406	0.9811	0.1586	0.9881	1.6525
	40	193.31	0.0008	0.9752	29.982	523.96	0.0411	0.9822	0.1536	0.9892	1.6680
	50	196.70	0.0008	0.9743	32.750	716.59	0.0419	0.9813	0.1463	0.9883	1.6918
	60	200.09	0.0008	0.9764	33.470	695.05	0.0409	0.9834	0.1477	0.9904	1.6972
150	30	267.83	0.0005	0.9745	36.830	410.12	0.0273	0.9815	0.1710	0.9885	1.5975
	40	273.40	0.0005	0.9739	40.207	540.66	0.0277	0.9808	0.1630	0.9878	1.6239
	50	279.99	0.0006	0.9739	43.469	670.97	0.0277	0.9808	0.1576	0.9878	1.6466
	60	284.05	0.0005	0.9757	36.854	890.59	0.0296	0.9827	0.1454	0.9897	1.6596
200	30	323.74	0.0004	0.9741	38.191	273.00	0.0205	0.9810	0.1941	0.9880	1.5064
	40	331.58	0.0004	0.9751	40.685	326.53	0.0206	0.9821	0.1874	0.9891	1.5306
	50	339.93	0.0004	0.9762	43.638	394.23	0.0206	0.9832	0.1810	0.9902	1.5551
	60	347.39	0.0004	0.9753	48.994	541.81	0.0210	0.9823	0.1709	0.9893	1.5875
250	30	371.70	0.0003	0.9777	38.697	205.88	0.0166	0.9847	0.2147	0.9917	1.4258
	40	382.54	0.0003	0.9778	40.515	225.85	0.0164	0.9848	0.2112	0.9918	1.4455
	50	395.81	0.0003	0.9764	40.708	219.11	0.0157	0.9834	0.2142	0.9904	1.4528
	60	402.42	0.0003	0.9771	45.685	288.60	0.0160	0.9841	0.2019	0.9911	1.4884



Fig; 5.3a-Freundlich isotherm for the removal of MG dye



Fig; 5.3b -.Langmuir isotherm for the removal of MG dye

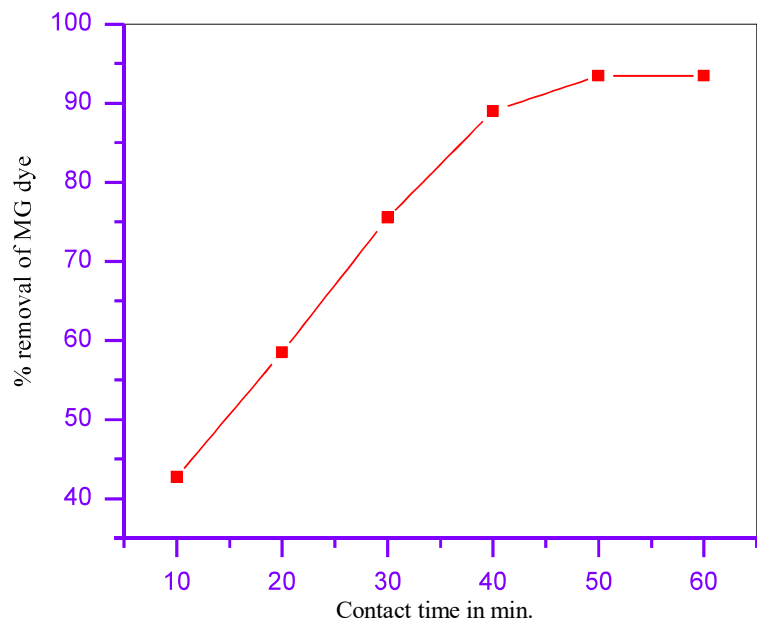


Fig: 5.1-Effect of contact time on th removal of MG dye
[MG]=50 mg/L;Adsorbent dose=50mg/50ml;pH=6.5;Temp=30⁰C

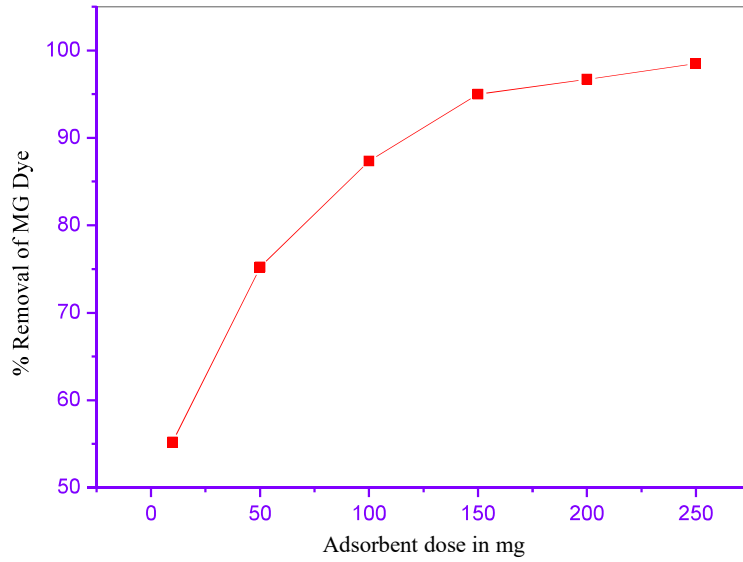


Fig: 5.2- Effect of Adsorbent dose on the removal of MG dye

[MG]=50mg/L;Contact Time 50min;Temp= 30⁰C

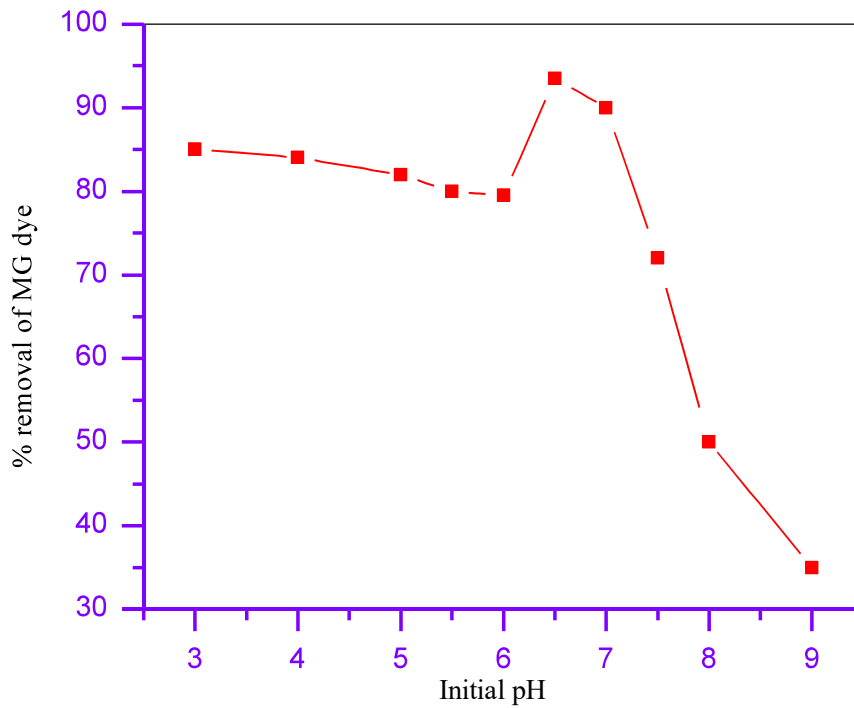


Fig: 5.3-Effect of initial pH on the removal of MG dye

[MG]=50 mg/L;Adsorbent dose=50mg/50ml;Temp=30⁰C

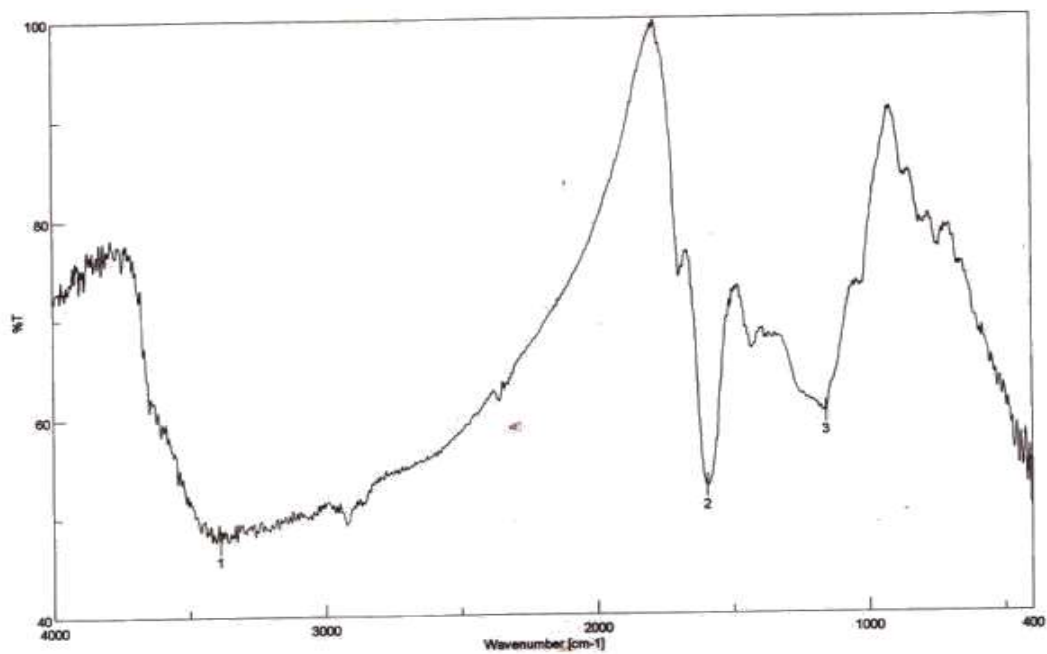


Fig.5. 4a FT-IR Spectrum of AGSNC before the adsorption

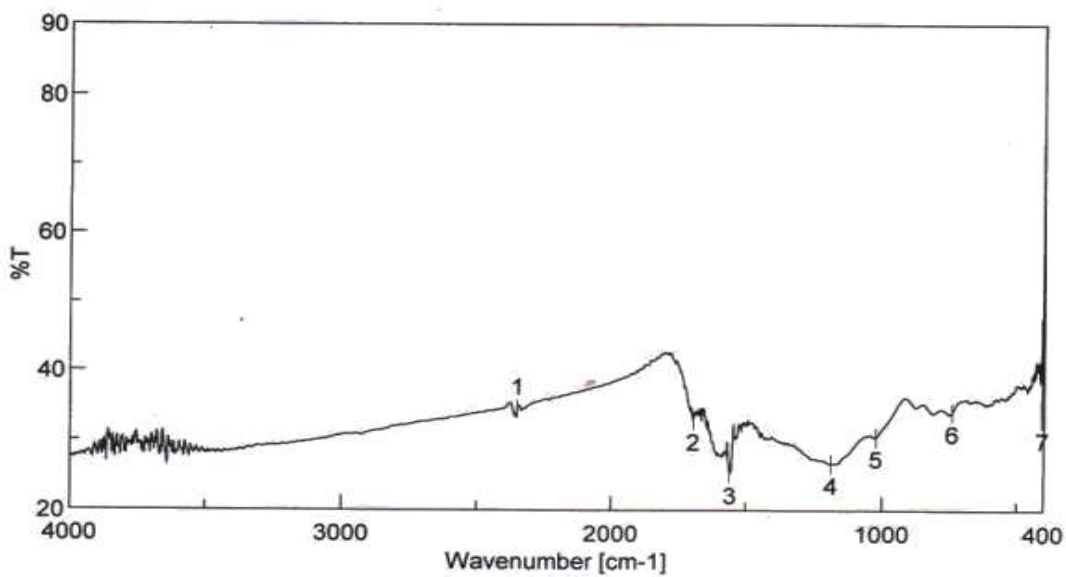


Fig.5. 4b FT-IR Spectrum after the adsorption of Malachite Green

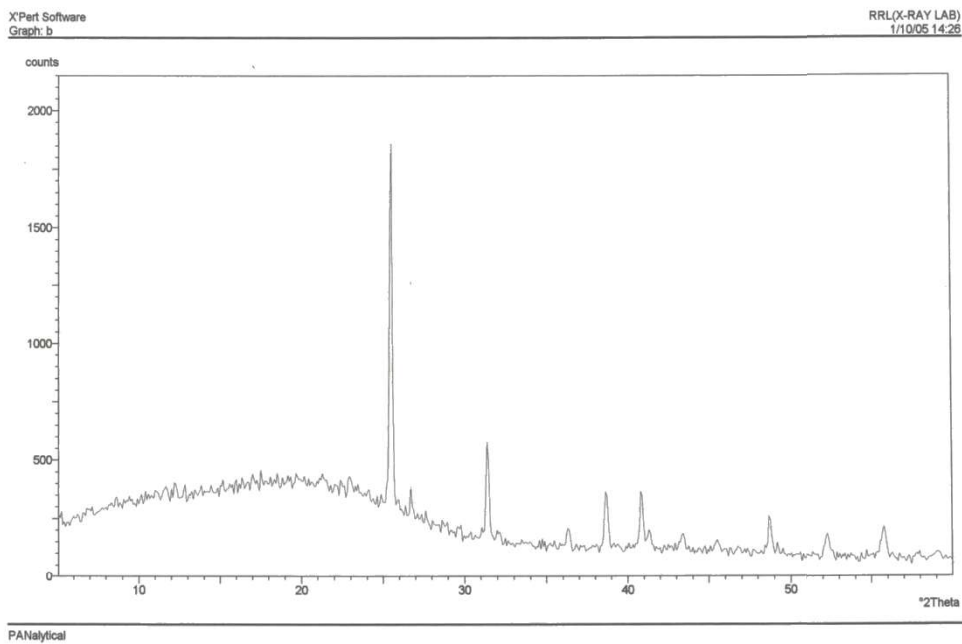


Fig.5.5a. XRD pattern of AGSNC before the adsorption

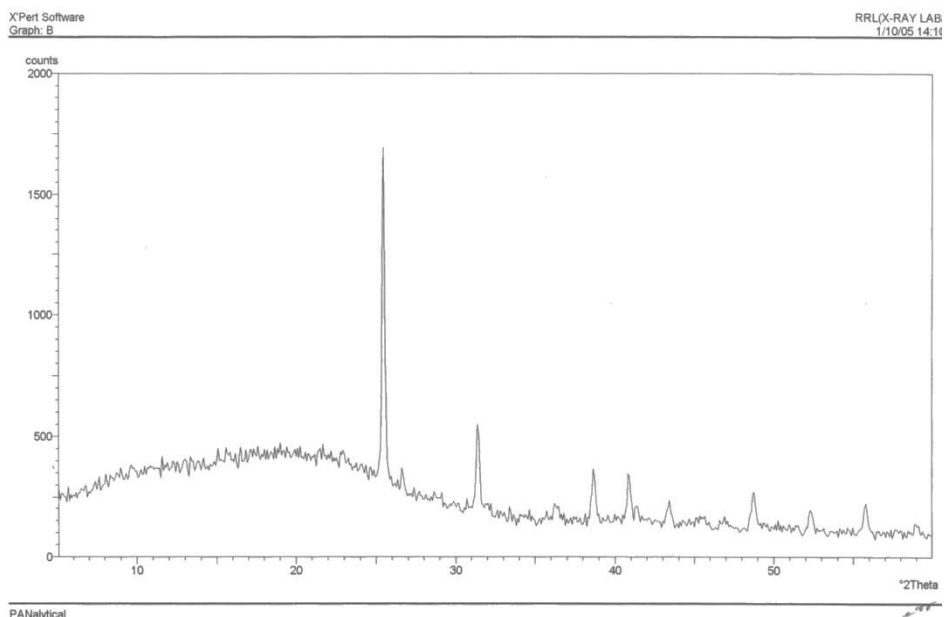


Fig.5.5b. XRD pattern of AGSNC after the adsorption of Malachite Green

5.2. ADSORPTION STUDIES OF RHODAMINE B DYE

5.2.1 Effect of contact time and initial Rh-B dye concentration

The experimental results for the adsorption at various concentrations (50 to 250 mg L⁻¹) with contact time are shown in Figure 5.6. The respective data's are presented in table 5.6, revealing that, percentage adsorption decreased with increase in initial dye concentration, but the actual amount of dye adsorbed per unit mass of AGSNC increased with an increase in dye concentration. It means that the adsorption is highly dependent on initial concentration of dye. It is because of the reason that at lower concentration, the ratio of the initial number of dye molecules to the available surface area is low. Subsequently the fractional adsorption becomes independent of initial concentration. However, at higher concentrations, the available sites of adsorption become fewer and hence the percentage removal of dye is depending upon initial concentration [211]. Equilibrium has been established at 50 minutes for all concentrations. Figure 5.6 reveals that the curve is single, smooth, and continuous, leading to saturation, suggesting the possibility of monolayer coverage of the Rh-B dye on the AGSNC adsorbent surface.

5.2.2 Effect of Dosage of AGSNC

The adsorption of Rh-B on AGSNC was studied by varying the concentration (50-250 mg/50ml) for 50 mg L⁻¹ of dye concentration. The percentage adsorption increased with an increase in the AGSNC concentration (Figure 5.7). This might be due to the increased AGSNC surface area and availability of more adsorption sites [212, 233]. Hence, the remaining parts of the experiments were carried out with an optimum dose of the adsorbent (50 mg/50 ml).

5.2.3 Effect of pH

One of the most important parameters controlling the adsorption process is pH. The effect of pH of the solution on the adsorption of Rh-B dye on AGSNC was determined. The result is shown in Figure 5.8. The pH of the solution was controlled by the addition of HCl or NaOH. The uptake of Rh-B dye at pH 7.5 was the minimum and a maximum uptake was obtained at pH 3.0 - 6.7. However, when the pH of the solution was increased (more than pH 7.5), the uptake of Rh-B was increased. It appears that a change in pH of the solution results in the formation of different ionic species, and different AGSNC surface charge. At pH values lower than 6.7, the Rh-B dye can enter the pore structure. As a pH values are higher than 6.7, the zwitterions form of Rh-B in water may increase the aggregation of Rh-B to form a bigger molecular form (dimer) and become unable to enter the pore structure of the AGSNC surface [213].

5.2.4 Effect of the Ionic Strength

The effect of sodium chloride on the adsorption of Rh-B on AGSNC shows that low solution concentration of NaCl had little influence on the adsorption capacity. At higher ionic strength the adsorption of Rh-B would be increased due to the partial neutralization of the positive charge on the AGSNC surface and a consequent compression of the electrical double layer by the chloride ion. The chloride ion can also enhance adsorption of Rh-B dye onto AGSNC by pairing of their charges and hence reducing the repulsion between the Rh-B dye molecules adsorbed on the surface. This initiates AGSNC to adsorb more amount of positive Rh-B dye [214].

5.2.5 Theory of Adsorption isotherm

To quantify the sorption capacity of the absorbent for the removal of Rh-B dyes, the most commonly used isotherm, namely Freundlich and Langmuir have been adopted.

5.2.5.1 Freundlich isotherm

The value of K_f and n are calculated from the intercept and slope of the plot of $\log q_e$ Vs $\log C_e$ respectively. The constant K_f and 'n' values are given in table 5.7. In general K_f value increases the adsorption capacity for a given adsorbate increases [195]. The magnitude of the exponent $1/n$ gives an indication of the favorability of adsorption. The value of $n > 1$ represents favorable adsorption condition [195]. The obtained value of $1/n$ are lying in the range of 1 to 10 confirms the favorable condition for adsorption. This was further supported by Langmuir isotherm.

5.2.5.2 Langmuir isotherm

The Langmuir isotherm model [215] is based on the assumption that the maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface.

The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e) shows that the adsorption obeys the Langmuir model. The Langmuir constant Q_m and 'b' were determined from the slope and intercept of the plot and are presented in table 5.7. The obtained values say that Rh-B dye was bound well to AGSNC by greater affinity. In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless separation factor R_L [196, 231] The obtained R_L values were in between 0 and 1 indicates the favorable adsorption of Rh-B for all initial concentration (C_o) and temperatures studied. The calculated R_L values are given in table 5.8.

5.2.6 Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0) and standard entropy change (ΔS^0) and these were calculated. The value of ΔH^0 and ΔS^0 were obtained from the slope and intercept of plot of $\ln K_0$ against $1/T$. The values of thermodynamic parameter calculated from equations are shown in table 5.9. The thermodynamic treatment of the sorption data indicates that ΔG^0 values were negative at all temperatures. From the results, it could be made out that physisorption is much more favorable for the adsorption of Rh-B dye. The positive values of ΔH^0 show the endothermic nature of adsorption and they govern the possibility of physical adsorption [216]. In the case of physical adsorption, while increasing the temperature of the system, the extent of dye adsorption increases, this rules out the possibility of chemisorptions [201]. The low ΔH^0 value depicts that dye is physisorbed onto adsorbent AGSNC. The negative value of ΔG^0 (table 5.9) shows that the adsorption is highly favorable and spontaneous. The positive value of ΔS^0 (table 5.9) shows the increased disorder and randomness at the solid solution interface of Rh-B dye with AGSNC adsorbent, while at the adsorption there are some structural changes in the dye and the adsorbent occurs. The adsorbed water molecules, which have been displaced by the adsorbate species, gain more translational entropy than is lost by the adsorbate molecules, thus allowing the prevalence of randomness in the system. The enhancement of adsorption capacity of the AGSNC at higher temperatures was attributed to the enlargement of pore size and activation of the adsorbent surface [217].

5.2.7 Adsorption kinetics

The study of adsorption dynamics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of Rh-B dye adsorption on the AGSNC was analyzed using pseudo second-order [198, 230], Elovich [199, 218] and intra-particle diffusion [200, 232] kinetic models.

The conformity between experimental data's and the model predicted values were expressed by the correlation coefficient (γ), (γ , values close or equal to 1). The relatively high correlation coefficient (γ) value indicates that all the above models successfully describes the kinetics of Rh-B dye adsorption on AGSNC adsorbent. The pseudo-second - order rate constants k_2 , the calculated 'h' values and the correlation coefficients (γ) confirms the fitness of the model towards the adsorption of Rh-B dye. The Elovich model parameters α , β , and correlation coefficient (γ) are also gives the better relevance. The values are summarized in table 5.10.

The intra-particle diffusion model slope was drawn between qt Vs $t^{1/2}$ gives the value of the intra-particle diffusion coefficient (k_{id}) and correlation coefficient (γ). The graph indicates the fitness of this model. The intercept value indicates that the curve is not passing through the origin, so the intra- particle diffusion is not only a rate controlling step. The intra-particle parameters are summarized in table 5.10. The thickness of Rh-B dye layer obtained from the intercept value indicates the adsorption clearly.

5.2.8 Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the dye. The effect of various reagents used for desorption studies

indicate that hydrochloric acid is a better reagent for desorption, because more than 70 % removal of adsorbed dye could be obtained. The reversibility of adsorbed dye in mineral acid is in agreement with the pH dependent results obtained. The desorption of dye by mineral acids medium indicates that the Rh-B dyes were adsorbed onto the AGSNC through physisorption [133, 202].

TABLE: 5.6. EQUILIBRIUM PARAMETERS FOR THE ADSORPTION OF Rh-B DYE ONTO AGSNC

M_0	Ce (Mg / L)				Qe (Mg / L)				Removal %			
	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C
50	2.654	2.306	2.009	1.824	94.69	95.39	95.98	96.35	94.69	95.39	95.98	96.35
100	12.56	11.09	9.105	7.683	174.9	177.8	181.8	184.6	87.44	88.91	90.89	92.32
150	28.11	24.82	21.67	18.89	243.8	250.4	256.7	262.2	81.26	83.45	85.55	87.41
200	54.68	50.52	21.67	41.80	290.6	299.0	356.7	316.4	72.66	74.74	89.16	79.10
250	85.32	80.05	46.14	69.95	329.4	339.9	407.7	360.1	65.87	67.98	81.54	72.02

TABLE: 5.7. LANGMUIR AND FREUNDLICH ISOTHERM PARAMETERS FOR THE ADSORPTION OF Rh-B ONTO AGSNC

Temp. (°C)	Langmuir parameters		Freundlich parameters	
	Q_m	b	K_f	n
30°C	365.42	0.0852	68.376	2.7525
40°C	375.34	0.0948	72.868	2.7599
50°C	505.13	0.0760	67.927	2.1097
60°C	393.29	0.1239	82.895	2.7610

TABLE: 5.8. DIMENSIONLESS SEPERATION FACTOR (R_L) FOR THE ADSORPTION OF Rh-B ONTO AGSNC

(C_i)	Temperature °C			
	30°C	40°C	50°C	60°C
50	0.1902	0.1742	0.2083	0.1390
100	0.1051	0.0954	0.1163	0.0747

150	0.0726	0.0657	0.0806	0.0511
200	0.0555	0.0501	0.0617	0.0388
250	0.0449	0.0405	0.0500	0.0313

TABLE: 5.9. THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF Rh-B ONTO AGSNC

(C₀)	ΔG°				ΔH°	ΔS°
	30°C	40°C	50°C	60°C		
50	-7259.1	-7883.4	-8522.4	-9063.3	11.095	60.620
100	-4887.7	-5417.0	-6178.8	-6883.2	15.547	67.259
150	-3695.9	-4210.2	-4776.1	-5364.0	13.172	55.610
200	-2462.5	-2823.2	-5659.7	-3684.5	17.913	67.835
250	-1656.6	-1959.0	-3989.7	-2617.3	13.707	51.143

TABLE: 5.10. THE KINETIC PARAMETERS FOR THE ADSORPTION OF Rh-B ONTO AGSNC

C₀	Temp °C	Pseudo second order				Elovich model			Intraparticle diffusion		
		q_e	k₂	γ	h	α	β	γ	K_{id}	γ	C
50	30	103.08	0.0016	0.9834	16.503	298.48	0.0775	0.9917	0.1522	0.9877	1.7002
	40	103.26	0.0016	0.9855	17.377	417.58	0.0811	0.9938	0.1436	0.9898	1.7178
	50	103.36	0.0017	0.9826	18.468	597.46	0.0849	0.9909	0.1357	0.9869	1.7345
	60	103.88	0.0017	0.9837	18.399	551.70	0.0835	0.9920	0.1376	0.9880	1.7332
100	30	190.49	0.0008	0.9828	29.672	484.95	0.0412	0.9911	0.1557	0.9871	1.6586
	40	193.32	0.0008	0.9839	30.612	580.16	0.0416	0.9922	0.1509	0.9882	1.6737
	50	196.67	0.0009	0.9830	33.407	795.40	0.0425	0.9913	0.1438	0.9873	1.6969
	60	200.01	0.0009	0.9851	34.123	769.17	0.0414	0.9934	0.1452	0.9894	1.7022
150	30	268.10	0.0005	0.9832	37.743	453.89	0.0276	0.9915	0.1677	0.9875	1.6049
	40	273.62	0.0005	0.9825	41.155	599.46	0.0281	0.9908	0.1599	0.9868	1.6307
	50	280.13	0.0006	0.9825	44.444	744.07	0.0281	0.9908	0.1547	0.9868	1.6528
	60	284.13	0.0005	0.9844	37.668	995.45	0.0300	0.9927	0.1427	0.9887	1.6655
200	30	324.48	0.0004	0.9827	39.345	302.27	0.0208	0.9910	0.1898	0.9870	1.5164
	40	332.25	0.0004	0.9838	41.856	361.62	0.0209	0.9921	0.1834	0.9881	1.5399
	50	340.50	0.0004	0.9849	44.831	436.63	0.0209	0.9932	0.1772	0.9892	1.5637
	60	347.90	0.0004	0.9840	50.260	601.48	0.0213	0.9923	0.1675	0.9883	1.5953
250	30	372.97	0.0003	0.9863	40.076	228.31	0.0169	0.9947	0.2094	0.9907	1.4385
	40	383.69	0.0003	0.9864	41.891	249.95	0.0166	0.9948	0.2061	0.9908	1.4575
	50	396.75	0.0003	0.9851	42.035	241.32	0.0159	0.9934	0.2092	0.9894	1.4644
	60	403.35	0.0003	0.9857	47.096	318.68	0.0163	0.9941	0.1973	0.9901	1.4989

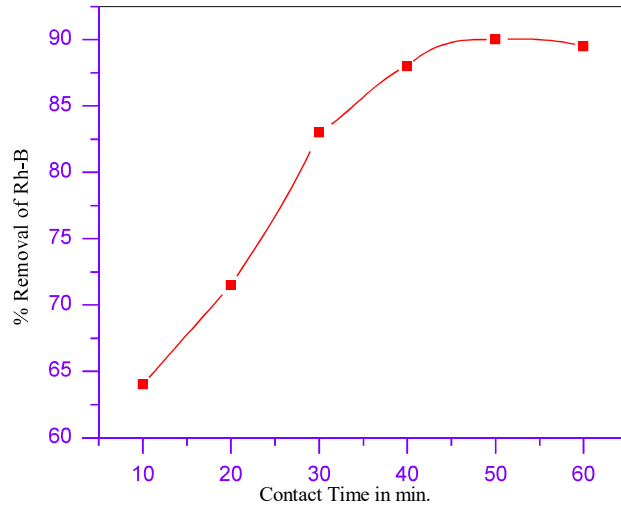


Fig: 5.6- Effect of Contact Time on the Removal of Rh-B dye
 [Rh-B]=50 mg/L;Temp= 30°C;Adsorbent dose=50mg/50ml

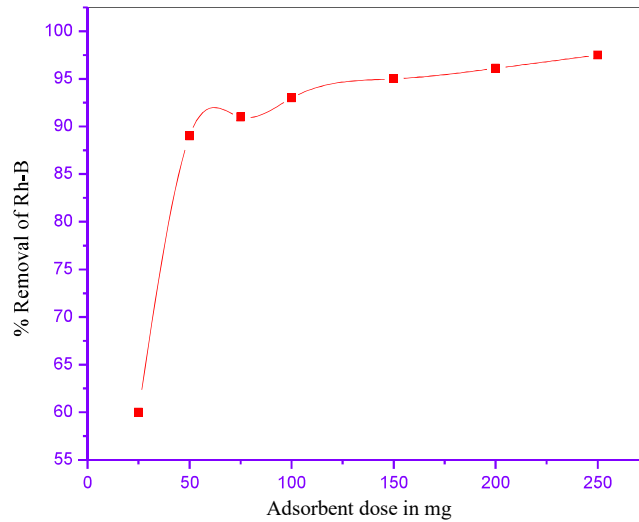
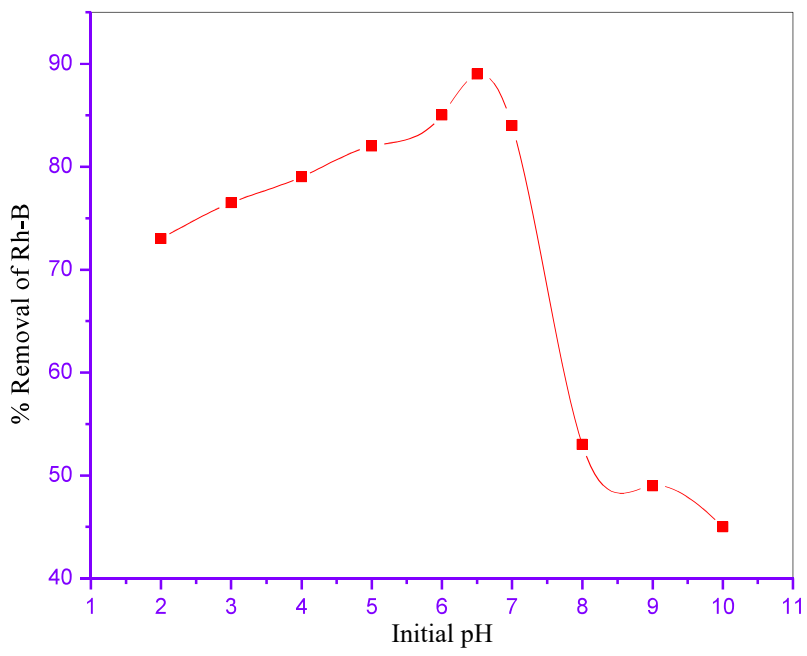


Fig: 5.7- Effect of Adsorbent dose on the removal of Rh-B Dye
 [Rh-B]=50mg/L; Temp= 30°C;Contact Time 50 min



Fig; 5.8- Effect of Initial pH on the removal of Rh-B Dye
[Rh-B]=50 mg/L;Temp= 30°C;Adsorbent dose=50mg/50ml

5.3. ADSORPTION STUDIES METHYLENE BLUE DYE

5.3.1 Effect of contact time and initial MB dye concentration

The experimental results of adsorptions of methylene blue at various concentrations from 50 to 250 mg L⁻¹ with contact time are shown in representative Figure 5.9. The equilibrium data's were collected in table 5.11 reveal that, percentage adsorption decreased with increase in initial dye concentration, but the actual amount of dye adsorbed per unit mass of adsorbent increased with increase in dye concentration. It means that the adsorption is highly dependent on initial concentration of dye. It is because of that lower concentration, the ratio of the initial number of MB dye molecules to the available surface area is low subsequently the fractional adsorption becomes independent of initial concentration. However, at high concentration the available sites of adsorption become fewer and hence the percentage removal of dye is dependent upon initial concentration [219]. Equilibrium has been established at 50 minutes for all concentrations. Figure 5.9 reveals that the curves are single, smooth, and continuous, leading to saturation, suggesting the possible monolayer coverage of the MB dyes on the AGSNC surface.

5.3.2 Effect of dosage

The adsorption of the Methylene Blue dye on AGSNC was studied by varying the adsorbent concentration (50–250 mg/50ml) for 50 mg L⁻¹ of dye concentration. The percent adsorption increased with increase in the adsorbent concentration (Figure 5.10). This was attributed to increased adsorbent surface area and availability of more adsorption sites. Hence, the entire studies were carried out with the adsorbent dose 25mg of adsorbent/ 50 ml of the adsorbate solution [220].

5.3.3 Effect of pH

One of the most important parameters controlling the adsorption process is pH. The effect of pH of the solution on the adsorption of MB dye on AGSNC was determined. The results were shown in Figure 5.11. The pH of the solution was controlled by the addition of HCl or NaOH. The uptake of MB dye at pH 7.5 was the minimum and a maximum uptake was obtained at pH 3.0-6.7. However, when the pH of the solution was increased (more than 7.5), the uptake of MB dye was increased. It appears that a change in pH of the solution results in the formation of different ionic species and different AGSNC surface charge [221]. As pH values are lower than 6.7, the MB dye can enter the pore structure. As a pH values are higher than 6.7, the zwitter ions form of MB dye in water may increase the aggregation of MB dye to form a bigger molecular form (dimer) and become unable to enter the pore structure of the AGSNC surface.

5.3.4 Effect of the Ionic Strength

The effect of sodium chloride on the adsorption of MB dye on AGSNC shows that a low solution concentration of NaCl had little influence on the adsorption capacity. At higher ionic strength the adsorption of MB dye would be increased due to the partial neutralization of the positive charge on the AGSNC surface and a consequent compression of the electrical double layer by the chloride ions. The chloride ion can also enhance adsorption of MB dye onto AGSNC by pairing of their charges and hence reducing the repulsion between the MB dye molecules adsorbed on the surface [214]. This initiates AGSNC to adsorb more of positive MB dye.

5.3.5 Theory of Adsorption isotherm

To quantify the sorption capacity of the absorbent for the removal of MB dye, the most commonly used isotherm, namely Freundlich and Langmuir have been adopted.

5.3.5.1 Freundlich isotherm

The value of K_f and n are calculated from the intercept and slope of the plot of $\log q_e$ Vs $\log C_e$ respectively. The constant K_f and 'n' values are given in table 5.12. In general K_f value increases the adsorption capacity for a given adsorbate increases [195]. The magnitude of the exponent $1/n$ gives an indication of the favorability of adsorption. The value of $n > 1$ represents favorable adsorption condition. The obtained values of $1/n$ lying in the range of 1 to 10 confirm the favorable condition for MB dye adsorption. This was further supported by Langmuir isotherm.

5.3.5.2 Langmuir isotherm

The Langmuir isotherm model [222, 229] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. Q_m and 'b' are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the amount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption efficiency of the adsorbent and 'b' (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption). The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e) shows that the adsorption obeys the Langmuir model. The Langmuir constant Q_m and 'b' were determined from the slope and intercept of the plot and are presented in table 5.12. The values predict better attraction of MB dye by AGSNC. In order to find out the feasibility of the isotherm, the essential characteristics of the

Langmuir isotherm can be expressed in terms of dimensionless constant separation factor, R_L [196, 223]. The obtained R_L values are in between 0 to 1 indicate favorable adsorption MB dye for all initial concentration (C_0) and temperatures studied. The calculated R_L values are given in table 5.13

5.3.6 Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0) and standard entropy change (ΔS^0) and these were calculated. The thermodynamic treatment of the sorption data indicates that ΔG^0 values were negative at all temperatures. From the results it could be made out that physisorption is much more favorable for the adsorption of MB dye. The positive values of ΔH^0 show the endothermic nature of adsorption and they govern the possibility of physical adsorption. In the case of physical adsorption, while increasing the temperature of the system, the extent of dye adsorption increases, this rules out the possibility of chemisorptions. The low ΔH^0 value that depicts dye is physisorbed onto adsorbent AGSNC. The negative values of ΔG^0 (table 5.14) show the adsorption is highly favorable and spontaneous. The positive value of ΔS^0 (table 5.14) show the increased disorder and randomness at the solid solution interface of MB dye with AGSNC adsorbent [201,224,225].

5.3.7 Adsorption kinetics

The study of adsorption dynamics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of MB dyes adsorption on the AGSNC were analyzed using pseudo second-order

[118] Elovich [199, 226] and intra-particle diffusion [200, 227] kinetic models. The conformity between experimental data and the model predicted values were expressed by the correlation coefficient (γ), (γ , values close or equal to 1). The relatively high correlation coefficient (γ) value obtained indicates that the above all models successfully describes the kinetics of MB dyes adsorption on AGSNC adsorbent.

The pseudo-second-order rate constants k_2 , the calculated 'h' values and the correlation coefficients (γ), the Elovich model parameters α , β , and correlation coefficient (γ) are summarized in table 5.15.

The slope of the plot of qt Vs $t^{1/2}$ will give the value of the intra-particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicates the fitness of this model. The intercept value indicates that the curve is not passing through the origin, so the intra-particle diffusion is not only the rate controlling step. The intra-particle parameters are summarized in table 5.15

5.3.8 Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the MB dye. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because more than 70 % removal of adsorbed dye could be made. The reversibility of adsorbed dye in mineral acid is in agreement with the pH dependent results obtained. The desorption of dye by mineral acids medium indicates that the MB dyes were adsorbed onto AGSNC through physisorption [228].

TABLE: 5.11. EQUILIBRIUM PARAMETERS FOR ADSORPTION OF MB DYE ONTO AGSNC

M_0	C_e (Mg / L)				Q_e (Mg / L)				Removal %			
	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C
50	2.3750	2.0637	1.7977	1.6328	95.250	95.873	96.405	96.734	95.250	95.873	96.405	96.734
100	11.243	9.9251	8.1492	6.8763	177.513	180.15	183.70	186.25	88.757	90.075	91.851	93.124
150	25.156	22.218	19.397	16.906	249.688	255.56	261.21	266.19	83.229	85.188	87.069	88.730
200	48.936	45.212	19.397	37.414	302.128	309.58	361.21	325.17	75.532	77.394	90.301	81.293
250	76.361	71.648	41.298	62.610	347.277	356.70	417.40	374.78	69.456	71.341	83.481	74.956

TABLE: 5.12. LANGMUIR AND FREUNDLICH ISOTHERM PARAMETERS FOR ADSORPTION OF MB DYE ONTO AGSNC

Temp. (°C)	Langmuir parameters		Freundlich parameters	
	Q_m	b	K_f	n
30°C	388.25	0.0868	70.435	2.6583
40°C	396.54	0.0974	75.218	2.6747
50°C	520.09	0.0823	71.579	2.0849
60°C	411.33	0.1287	85.826	2.6912

TABLE: 5.13. DIMENSIONLESS SEPARATION FACTOR (R_L) FOR THE ADSORPTION OF MB DYE ONTO AGSNC

(C_i)	Temperature °C			
	30°C	40°C	50°C	60°C
50	0.1872	0.1704	0.1955	0.1345
100	0.1033	0.0931	0.1083	0.0721
150	0.0713	0.0641	0.0749	0.0493
200	0.0544	0.0488	0.0573	0.0374
250	0.0440	0.0395	0.0463	0.0301

TABLE: 5.14. THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF MB DYE ONTO AGSNC

(C_0)	ΔG°				ΔH°	ΔS°
	30°C	40°C	50°C	60°C		
50	-7553.3	-8185.2	-8832.1	-9381.4	11.041	61.413
100	-5204.8	-5739.5	-6504.8	-7214.4	15.368	67.715
150	-4035.6	-4552.5	-5121.2	-5712.7	12.922	55.905
200	-2839.6	-3202.6	-5991.7	-4067.4	17.432	67.477
250	-2069.5	-2373.3	-4350.6	-3035.1	13.162	50.690

TABLE: 5.15. THE KINETIC PARAMETERS FOR THE ADSORPTION OF MB DYE ONTO AGSNC

C_0	Temp °C	Pseudo second order				Elovich model			Intraparticle diffusion		
		q_e	k_2	γ	h	α	β	γ	K_{id}	γ	C
50	30	102.47	0.0018	0.9834	19.073	663.01	0.0866	0.9917	0.1337	0.9877	1.7363
	40	102.66	0.0019	0.9855	20.027	967.97	0.0906	0.9938	0.1263	0.9898	1.7514
	50	102.79	0.0020	0.9826	21.229	1447.77	0.0949	0.9909	0.1195	0.9869	1.7659
	60	103.25	0.0020	0.9837	21.135	1315.08	0.0933	0.9920	0.1212	0.9880	1.7646
100	30	190.90	0.0010	0.9828	35.008	1140.85	0.0460	0.9911	0.1353	0.9871	1.7020
	40	193.46	0.0010	0.9839	35.940	1379.61	0.0465	0.9922	0.1315	0.9882	1.7146
	50	196.53	0.0010	0.9830	38.953	1930.78	0.0475	0.9913	0.1257	0.9873	1.7342
	60	199.50	0.0010	0.9851	39.635	1820.40	0.0463	0.9934	0.1272	0.9894	1.7385
150	30	270.39	0.0006	0.9832	45.508	1074.88	0.0309	0.9915	0.1441	0.9875	1.6580
	40	275.45	0.0006	0.9825	49.192	1441.64	0.0314	0.9908	0.1380	0.9868	1.6793
	50	281.34	0.0007	0.9825	52.700	1792.26	0.0314	0.9908	0.1341	0.9868	1.6975
	60	284.92	0.0005	0.9844	44.564	2562.85	0.0335	0.9927	0.1240	0.9887	1.7082
200	30	330.55	0.0005	0.9827	49.225	718.48	0.0233	0.9910	0.1600	0.9870	1.5871
	40	337.63	0.0005	0.9838	51.857	861.30	0.0233	0.9921	0.1554	0.9881	1.6058
	50	345.16	0.0005	0.9849	55.003	1040.59	0.0233	0.9932	0.1509	0.9892	1.6248
	60	351.99	0.0005	0.9840	61.030	1461.75	0.0238	0.9923	0.1434	0.9883	1.6505
250	30	383.40	0.0004	0.9863	51.970	549.70	0.0189	0.9947	0.1733	0.9907	1.5268
	40	393.09	0.0003	0.9864	53.729	591.96	0.0185	0.9948	0.1715	0.9908	1.5410
	50	404.62	0.0003	0.9851	53.426	548.54	0.0178	0.9934	0.1749	0.9894	1.5456
	60	410.98	0.0004	0.9857	59.182	740.51	0.0182	0.9941	0.1659	0.9901	1.5730

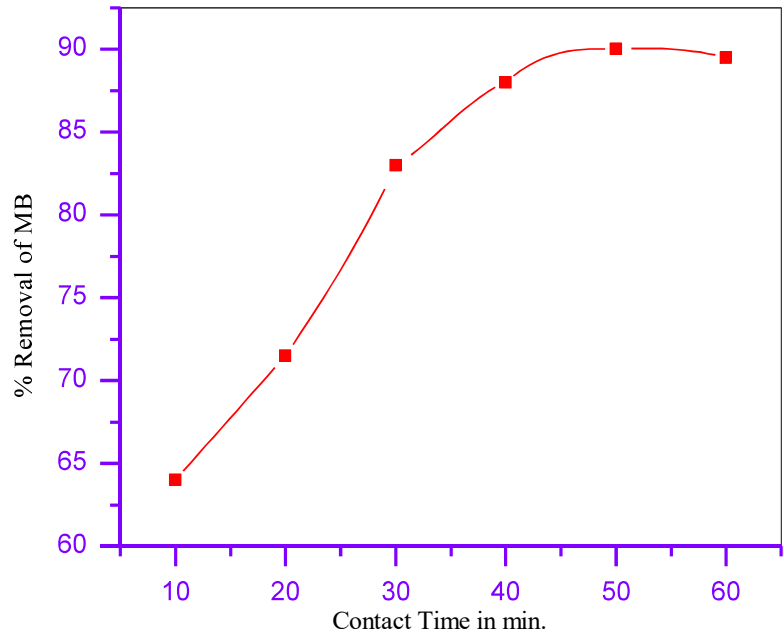


Fig: 5.9- Effect of Contact Time on the Removal of MB Dye
 [MB]=50 mg/L;Temp= 30°C;Adsorbent dose=50mg/50ml

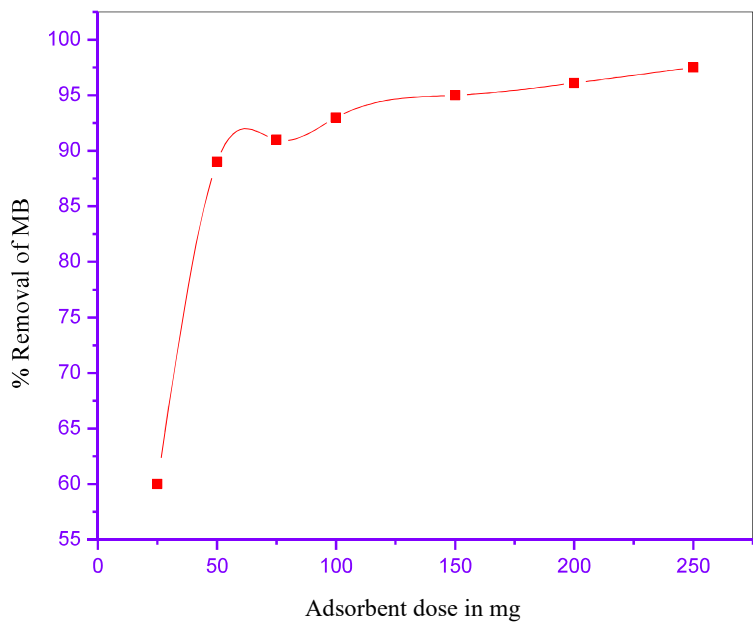
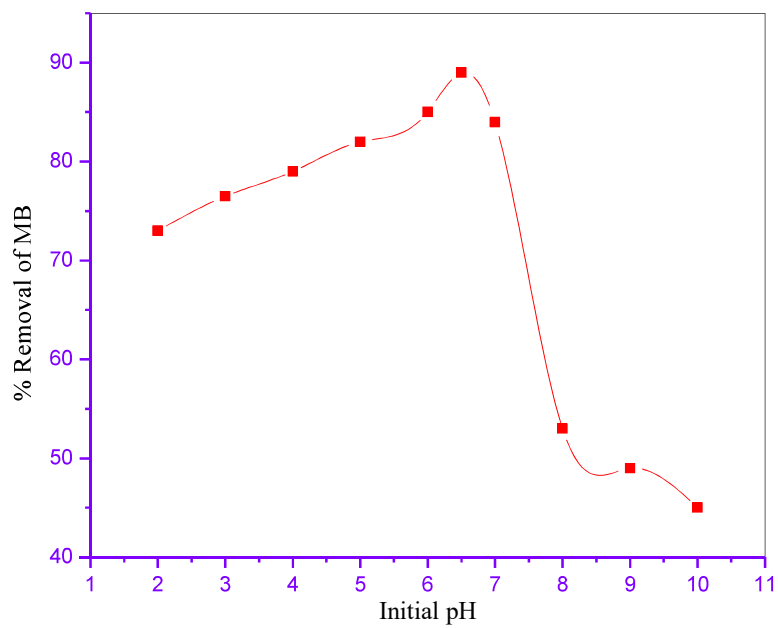


Fig: 5.10- Effect of Adsorbent dose on the removal of MB Dye
 [MB]=50mg/L;Contact Time 50min;Temp= 30°C



Fig; 5.11- Effect of Initial pH on the removal of MB Dye
[MB]=50 mg/L;Temp= 30°C;Adsorbent dose=50mg/50ml

5.4 ADSORPTION STUDIES OF SAFRANIN DYE

5.4.1 Effect of contact time and initial SF dye concentration

The experimental results of adsorptions SF at various concentrations from 50 to 250 mg L⁻¹ with contact time are shown in representative Figure 5.12. The equilibrium data's collected in table 5.16 revealed that, percentage adsorption decreased with increase in initial dye concentration, but the actual amount of dye adsorbed per unit mass of adsorbent increased with increase in dye concentration. It means that the adsorption is highly dependent on initial concentration of dye. It is because of that lower concentration the ratio of the initial number of dye molecules to the available surface area is low subsequently the fractional adsorption becomes independent of initial concentration. However, at high concentration the available sites of adsorption become fewer and hence the percentage removal of dye is depending upon initial concentration [219]. Equilibrium has been established at 50 minutes for all concentrations. Figure 5.12 reveals that the curves are single, smooth, and continuous, leading to saturation, suggesting the possible monolayer coverage of the dyes on the AGSNC surface.

5.4.2 Effect of dosage

The adsorption of the Safranin dye on AGSNC was studied by varying the adsorbent concentration (50-250 mg/50ml) for 50 mg L⁻¹ of dye concentration. The percentage adsorption increased with increase in the adsorbent concentration (Figure 5.13). This was attributed to increased adsorbent surface area and availability of more adsorption sites. Hence, the entire studies were carried out with the adsorbent dose 25mg of adsorbent/ 50 ml of the adsorbate solution [220].

5.4.3 Effect of pH

One of the most important parameters controlling the adsorption process is pH. The effect of pH of the solution on the adsorption of MB dye on AGSNC was determined. The results were shown in Figure 5.14. The pH of the solution was controlled by the addition of HCl or NaOH. The uptake of SF dye at pH 7.5 was the minimum and a maximum uptake was obtained at pH 3.0-6.7. However, when the pH of the solution was increased (more than 7.5), the uptake of SF dye was increased. It appears that a change in pH of the solution results in the formation of different ionic species, and different AGSNC surface charge [221]. As pH values are lower than 6.7, the SF dye can enter the pore structure. As a pH values are higher than 6.7, the zwitterions form of SF dye in water may increase the aggregation of SF dye to form a bigger molecular form (dimer) and become unable to enter the pore structure of the AGSNC surface.

5.4.4 Effect of the Ionic Strength

The effect of sodium chloride on the adsorption of SF dye on AGSNC shows that a low solution concentration NaCl had little influence on the adsorption capacity (Figure 5.15) At higher ionic strength the adsorption of SF dye will be increased due to the partial neutralization of the positive charge on the AGSNC surface and a consequent compression of the electrical double layer by the chloride ions. The chloride ion can also enhance adsorption of SF dye onto AGSNC by pairing of their charges and hence reducing the repulsion between the SF dye molecules adsorbed on the surface [214]. This initiates AGSNC to adsorb more of positive SF dye.

5.4.5 Theory of Adsorption isotherm

To quantify the sorption capacity of the absorbent for the removal of SF dye, the most commonly used isotherm, namely Freundlich and Langmuir have been adopted.

5.4.5.1 Freundlich isotherm

The value of K_f and n are calculated from the intercept and slope of the plot of $\log q_e$ Vs $\log C_e$ respectively. The constant K_f and 'n' values are given in table 5.17. In general K_f value increases the adsorption capacity for a given adsorbate increases [195]. The magnitude of the exponent $1/n$ gives an indication of the favorability of adsorption. The value of $n > 1$ represents favorable adsorption condition. The obtained value of $1/n$ lying in the range of 1 to 10 confirms the favorable condition for SF adsorption. This was further supported by Langmuir isotherm.

5.4.5.2 Langmuir isotherm

The Langmuir isotherm model [222, 229] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. Q_m and 'b' are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the amount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption efficiency of the adsorbent and 'b' (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption). The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e) shows that the adsorption obeys the Langmuir model. The Langmuir constant Q_m and 'b' were determined from the slope and intercept of the plot and are presented in table 5.17. This one shows the effectiveness of AGSNC towards SF. In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir

isotherm could be expressed in terms of dimensionless constant separation factor R_L [196, 223]. The obtained R_L values are in between 0 to 1 indicates favorable adsorption for SF all initial concentration (C_o) and temperatures studied. The calculated R_L values are given in table 5.18.

5.4.6 Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0) and standard entropy change (ΔS^0) and these were calculated. The thermodynamic treatment of the sorption data indicates that ΔG^0 values were negative at all temperatures. From the results it could be made out that physisorption is much more favorable for the adsorption of SF dye. The positive values of ΔH^0 show the endothermic nature of adsorption and they govern the possibility of physical adsorption. In the case of physical adsorption, while increasing the temperature of the system, the extent of dye adsorption increases, this rules out the possibility of chemisorptions. The low ΔH^0 value that depicts SF dye was physisorbed onto adsorbent AGSNC. The negative values of ΔG^0 (table 5.19) show the adsorption is highly favorable and spontaneous. The positive value of ΔS^0 (table 5.19) show the increased disorder and randomness at the solid solution interface of SF dye with AGSNC adsorbent [201,224,225].

5.4.7 Adsorption kinetics

The study of adsorption dynamics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of SF dye adsorption on the AGSNC were analyzed using pseudo second-order

[118] Elovich [199, 226] and intra-particle diffusion [200, 227] kinetic models. The conformity between experimental data's and the model predicted values was expressed by the correlation coefficient (γ), (γ values close or equal to 1). The relatively high correlation coefficient (γ) value indicates that the above all models successfully describes the kinetics of SF dye adsorption on AGSNC adsorbent.

The pseudo-second-order rate constants k_2 , the calculated 'h' values and the correlation coefficients (γ), the Elovich model parameters α , β , and correlation coefficient (γ) are summarized in table 5.20.

The slope of the plot of qt Vs $t^{1/2}$ will give the value of the intra -particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicates the fitness of this model. The intercept value indicates that the curve is not passing through the origin. So the intra-particle diffusion is not only rate controlling step. The intra-particle parameters are summarized in table 5.20. From the intercept the thickness of SF layer formed on AGSNC was determined.

5.4.8 Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the dye. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because more than 70 % removal of adsorbed dye could be obtained. The reversibility of adsorbed SF dye in mineral acid in agreement with the pH dependent results obtained. The desorption of dye by mineral acids medium indicates that the SF dye were adsorbed onto AGSNC through physisorption [228].

TABLE: 5.16. EQUILIBRIUM PARAMETERS FOR ADSORPTION OF SF DYE ONTO AGSNC

M_0	C_e (Mg / L)				Q_e (Mg / L)				Removal %			
	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C
50	2.787	2.421	2.109	1.916	94.43	95.16	95.78	96.17	94.43	95.16	95.78	96.17
100	13.19	11.64	9.56	8.07	173.6	176.7	180.9	183.9	86.81	88.36	90.44	91.93
150	29.51	26.07	22.76	19.83	241.0	247.9	254.5	260.3	80.32	82.62	84.83	86.78
200	57.42	53.05	22.76	43.90	285.2	293.9	354.5	312.2	71.29	73.48	88.62	78.05
250	89.59	84.06	48.45	73.46	320.8	331.9	403.1	353.1	64.16	66.38	80.62	70.62

TABLE: 5.17. LANGMUIR AND FREUNDLICH ISOTHERM PARAMETERS FOR ADSORPTION OF SF ONTO AGSNC

Temp. (°C)	Langmuir parameters		Freundlich parameters	
	Q_m	b	K_f	n
30°C	354.66	0.0850	67.609	2.8018
40°C	365.33	0.0943	71.964	2.8042
50°C	498.04	0.0735	66.410	2.1220
60°C	384.75	0.1225	81.725	2.7967

TABLE: 5.18. DIMENSIONLESS SEPARATION FACTOR (R_L) FOR ADSORPTION OF SF ONTO AGSNC

(C_i)	Temperature °C			
	30°C	40°C	50°C	60°C
50	0.1904	0.1750	0.2139	0.1404
100	0.1052	0.0959	0.1198	0.0755
150	0.0727	0.0660	0.0832	0.0516
200	0.0555	0.0504	0.0637	0.0392
250	0.0449	0.0407	0.0516	0.0316

TABLE: 5.19. THERMODYNAMIC PARAMETERS FOR ADSORPTION OF SF ONTO AGSNC

(C ₀)	ΔG°				ΔH°	ΔS°
	30°C	40°C	50°C	60°C		
50	-7128.9	-7749.9	-8385.5	-8922.7	11.121	60.276
100	-4746.4	-5273.5	-6034.0	-6736.4	15.634	67.080
150	-3543.5	-4057.0	-4622.1	-5208.7	13.295	55.512
200	-2291.5	-2651.6	-5512.1	-3512.4	18.153	68.069
250	-1467.3	-1769.7	-3827.8	-2427.6	13.984	51.440

TABLE: 5.20. THE KINETIC PARAMETERS FOR ADSORPTION OF SF ONTO AGSNC

C ₀	Temp °C	Pseudo second order				Elovich model			Intraparticle diffusion		
		q _e	k ₂	γ	h	α	β	γ	K _{id}	γ	C
50	30	103.4	0.0014	0.9900	15.46	216.6	0.0738	0.9910	0.1613	0.9899	1.6826
	40	103.6	0.0015	0.9921	16.30	297.8	0.0772	0.9931	0.1521	0.9920	1.7014
	50	103.7	0.0016	0.9892	17.35	418.5	0.0809	0.9902	0.1436	0.9891	1.7192
	60	104.2	0.0016	0.9903	17.29	389.0	0.0795	0.9913	0.1456	0.9902	1.7179
100	30	190.4	0.0008	0.9894	27.51	343.8	0.0392	0.9904	0.1659	0.9893	1.6370
	40	193.3	0.0008	0.9905	28.45	409.5	0.0397	0.9915	0.1606	0.9904	1.6534
	50	196.8	0.0008	0.9896	31.16	556.7	0.0405	0.9906	0.1527	0.9895	1.6785
	60	200.3	0.0008	0.9917	31.89	543.9	0.0395	0.9927	0.1541	0.9916	1.6844
150	30	267.2	0.0005	0.9898	34.62	320.9	0.0263	0.9908	0.1797	0.9897	1.5782
	40	272.9	0.0005	0.9891	37.91	421.2	0.0267	0.9901	0.1710	0.9890	1.6064
	50	279.7	0.0005	0.9891	41.11	522.4	0.0268	0.9901	0.1650	0.9890	1.6306
	60	283.9	0.0004	0.9910	34.88	680.3	0.0286	0.9920	0.1521	0.9909	1.6444
200	30	321.9	0.0003	0.9893	35.41	213.4	0.0198	0.9903	0.2053	0.9892	1.4801
	40	330.0	0.0003	0.9904	37.86	255.1	0.0199	0.9914	0.1979	0.9903	1.5063
	50	338.5	0.0004	0.9915	40.76	307.9	0.0199	0.9925	0.1908	0.9914	1.5327
	60	346.2	0.0004	0.9906	45.93	420.8	0.0203	0.9916	0.1798	0.9905	1.5674
250	30	368.6	0.0003	0.9930	35.38	160.3	0.0161	0.9940	0.2289	0.9929	1.3921
	40	379.8	0.0003	0.9931	37.21	176.7	0.0158	0.9941	0.2246	0.9930	1.4138
	50	393.6	0.0002	0.9917	37.51	173.5	0.0151	0.9927	0.2274	0.9916	1.4222
	60	400.2	0.0003	0.9924	42.28	227.0	0.0155	0.9934	0.2138	0.9923	1.4607

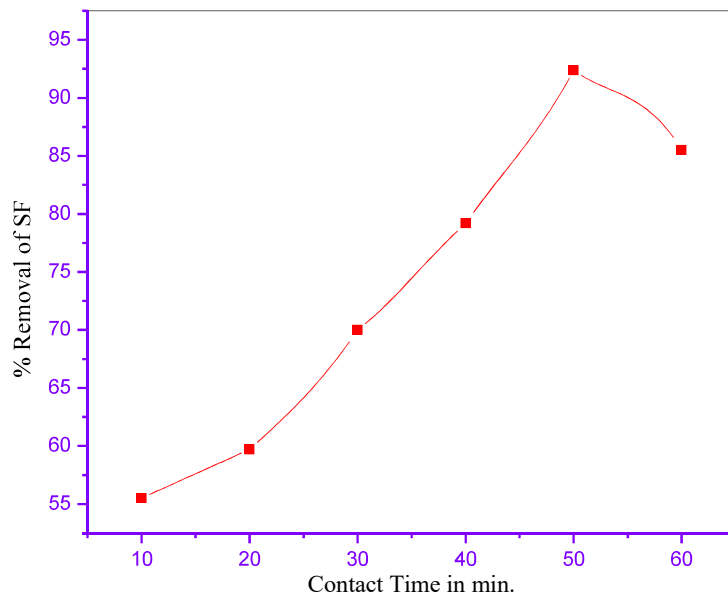


Fig:5.12- Effect of Contact Time on the Removal of SF
 [SF]=50 mg/L;Temp= 30⁰C;Adsorbent dose=50mg/50ml

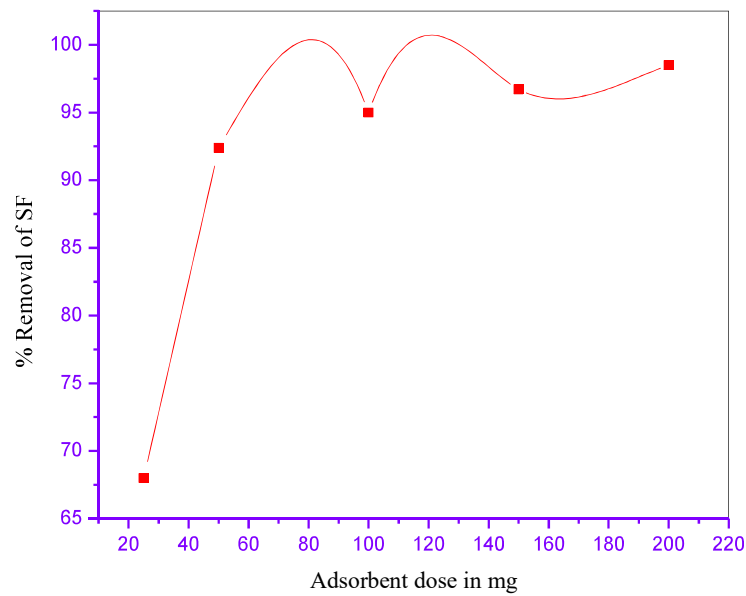
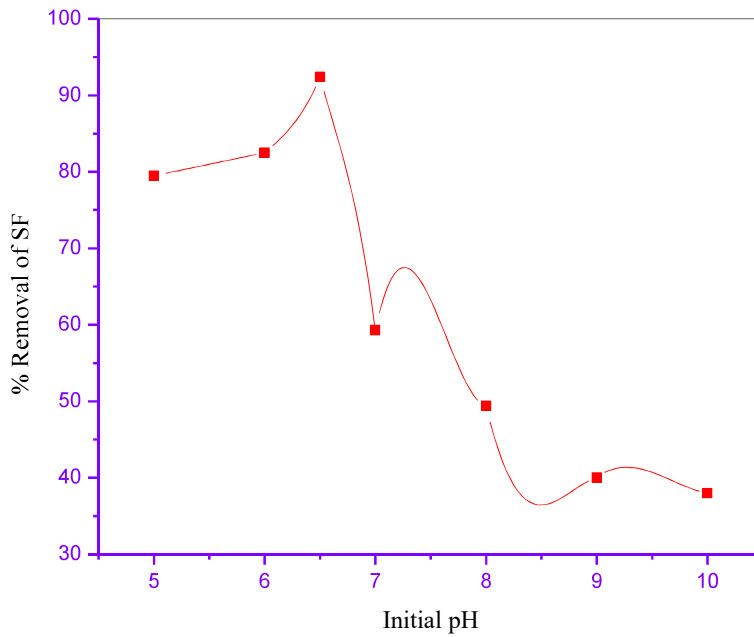


Fig:5.13- Effect of Adsorbent dose on the removal of SF dye
 [SF]=50mg/L;Contact Time 50min;Temp= 30⁰C



Fig;5.14- Effect of Initial pH on the removal of SF dye
 [SF]=50 mg/L;Temp= 30^oC;Adsorbent dose=50mg/50ml

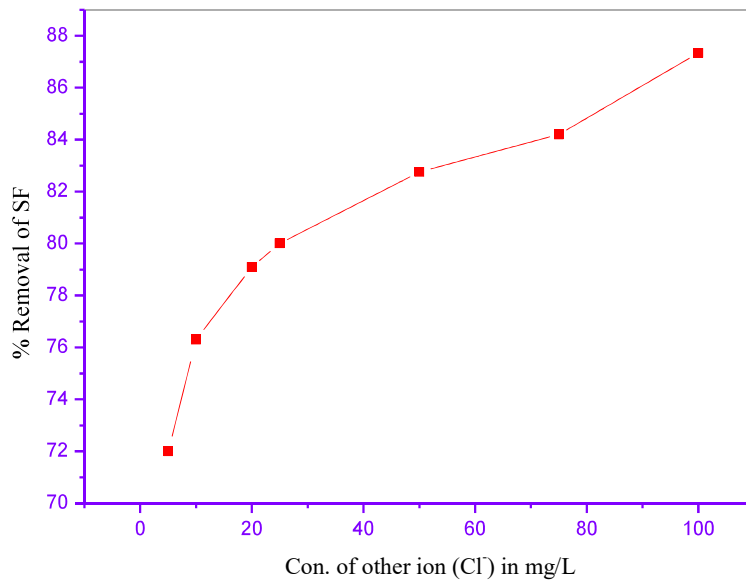


Fig.5.15-Effect ionic strength on the adsorption of SF dye
 [SF]=50 mg/L;Contact time=50 min;Dose=50 mg/50 ml