Equilibrium, Kinetic and Thermodynamic Study on Malachite Green dye Removal from Aqueous Solution using Activated Los Pantanos De Villa Nano Carbon

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Abstract

The research of the present work was to investigate the removal of Malachite Green dye from aqueous solution by using Los Pantanos De Villa Nano Carbon (ALPNC). Generally, dyes are used in chemical, textile, paper, printing, leather, plastics and various food industries. The need for the treatment of dye contaminated waste water passed out from the industry. In this study, Los Pantanos De Villa Nano Carbon was studied for its potential use as an adsorbent for removal of Malachite Green dye. The various factors affecting adsorption, such as initial dye concentration, contact time, adsorbent dose, effect of temperature and pH were evaluated. The experimental data were fitted into the pseudo-second order kinetic model. The equilibrium of adsorption was modeled by using the Langmuir and Freundlich isotherm models. The objective of the present work suggests the ALPNC may be utilized as a low cost adsorbent for Malachite Green dye removal from aqueous solution.

Key words: Activated Los Pantanos De Villa Nano Carbon (ALPNC); Malachite Green dye (MG); Adsorption isotherm; Kinetics; Equilibrium models

1. Introduction

With the world population set to break seven billion sometime next year, the management and use of natural resources is pushing to the forefront of world concern. With more people entering the worldwide market, an increase in products to meet their needs is inevitable. Individuals, businesses, and industries are seeing not only the long term monetary benefit of using resources wisely, but also the aesthetic and health benefits that come from environmental stewardship. This is seen from the changing of light bulbs at home to the tightening of national government and world standards for environmental quality[1]. With potable water essential to life, no where else are these standards more important than the area of water quality. Not only is water essential for life, it has become the primary workhorse of industries around the world as a working fluid, transport medium, heat transfer fluid, cleaning agent, etc. Unfortunately this has often led to the degradation of water quality as harmful effluents are returned to the environment with various contaminants from these processes [2]. One of the most startling groups of water contaminants are those of dyes due to their accumulation in biological systems and their toxicity even at relatively low concentrations [3-5].

In the present investigation the adsorption of MG dye on activated carbon prepared from Los Pantanos De Villa. By carbonization with sulphuric acid has been achieved. The kinetic and equilibrium adsorption data obtained were utilized to characterize the sample prepared [6-7]. The amounts and rates of adsorption of MG dye using above activated nano carbon from water were then measured. Three simplified kinetic models including pseudo first order, Pseudo second order equations and Elovich equations were used to describe the adsorption process.

2. Materials and methods:

All the reagents used for the current investigation were of GR grade from Scientific Equipment Company, Trichy, India. Stock solution (1000 mg/L) of MG dye was prepared by dissolving 1000 mg of MG dye in double distilled water. The solution was further diluted to the required concentrations before use. Before mixing the adsorbent, the pH of each MG dye solution was adjusted to the required value by 0.1 M NaOH or 0.1 M HCl solution**.**

2.1 Preparation of Adsorbent:

Los Pantanos De Villa was collected from local area of Pudukkottai district, Tamilnadu, India. It was dried, charred with excess quantity of concentrated sulphuric acid keeping at 120^{o}C for 10 hours. Then the resultant carbon was washed with excess quantity of distilled water and dried at 110^{o}C for 1 hour and the material obtained was soaked in 5% sodium bicarbonate solution and allowed to stand overnight to remove any residual acid. The material was thoroughly washed with hot distilled water until washings were nearly of neutral effect. To eliminate surface groups by thermal activation, the carbonized material was activated at 1200 °C for 6 hrs in a furnace. The resulting carbons were ground in a mill.

Los Pantanos De Villa

2.2 Adsorbent characterization

Adsorbent characterization was performed by means of spectroscopic and quantitative analysis. The surface area of the adsorbent was determined by Quanta chrome surface area analyzer. The pH of aqueous slurry was determined by soaking 1g of biomass in 50 mL distilled water, stirred for 24 h and filtered and the final pH was measured. The physico-chemical characteristics of the adsorbent were determined using standard procedures. The equilibrium MG dye concentration was determined by using UV-VIS Spectrophotometer (Systronics, Vis double beam Spectro 1203). For stirring purpose magnetic stirrer was used. The pH of zero-point charge or pH_{ZPC} was determined based on the previous method [9].

Table: 1 physicochemical characteristics of adsorbent

Analysis	Value
pH_{slurry}	5.8
pH_{zpc}	4.00
Specific gravity	0.100
Moisture content, %	0.220
Bulk density, g cm^{-3}	0.190
Particle density, g cm^{-3}	0.222
Conductivity, µS/cm	38.03
Surface area, m^2/g	23.22
Na^+, mg L^{-1}	108
K^+, mg L^{-1}	520

2.3 Batch Adsorption experiments:

The Batch adsorption experiments were conducted in 250 mL Erlenmeyer flask with 50mL of standard Dye solution and were agitated in a thermo state – controlled shaker at 120 rpm. All experiment were conducted at 30-60 ºC, unless otherwise was stated.

The effect of initial pH on the adsorption of the MG dye onto the activated carbon was studied across a pH range of 2.0 – 9.0 with a fixed adsorbent concentration (25 mg/50ml of 50mgL^{-1} of dye solution). The pit value of the initial dye solution (50mgL^{-1}) was adjusted using a 0.1M HCl or NaOH solution. Activated carbon (0.0250g) was then added to the solution and agitated for enough time to achieve equilibrium. The effect of the agitation period was also studied at a constant concentration of 50 mg L^{-1} Dye solution and a fixed adsorbent concentration of 25mg/50mL at the optimum pH. After agitation the sample solution was withdrawn at different time intervals (10-60min) and centrifuged at 3600 rpm for 10 min. Subsequently an aliquot of the supernatant was used for determination of the remaining dye concentration, and the remainder was poured back into the original solution. The determination of the effect of the initial concentration of the uptake of the dye was conducted by varying the dye concentration from 50 to 250 mg L^{-1} at a constant activated carbon dosage of 25 mg at optimum pH and agitation period. The effect of temperature on the adsorption characteristics was studied by determining the adsorption isotherms from 303 – 333K at a dye concentration of 50-250mg/L.

The percentage removal of the dyes and the amount of dye taken up by the adsorbent was calculated by applying following equations.

$$\%\,\text{Removal} = \frac{C_i - C_t}{C_i} \times 100 \qquad (1)$$

$$Q = \frac{(C_i - C_t)}{m} V \qquad (2)$$

Where C_i and C_t are the initial and liquid phase concentrations of MG dye at time 't' (mg L^{-1}) Q is the amount of dye adsorbed on the adsorb of at any time (mg g^{-1}), m(g) the mass of the adsorbent sample used and V the volume of the dye solution (L).

3. Results and Discussion:

3.1 Effect of contact time:

The Fig. 1 shows that the adsorption of MG dye from an aqueous solution reached equilibrium with in 40 min. The contact time significantly affected the dye uptake. The adsorption of dye by all studied adsorbents sharply increased in the first 30 min. The rapid adsorption at the initial stage was probably due to the great concentration gradient between the dye in solution and the dye in the adsorbent because there must be a number of vacant sites available in the beginning. The progressive increase in adsorption and, consequently, the attainment of equilibrium adsorption is initially due to the limited mass transfer of the MG dye from the bulk solution to the external surface of the adsorbent, and is subsequently due to the slower internal mass transfer within the adsorbent particles [8].

3.2 Effect of initial Dye concentration:

The experimental results of adsorption of MG dye on ALPNC at various initial concentration (50, 100, 150, 200 and 250 mg/L) for MG dye in terms of equilibrium data are given in table 2. The initial concentration provides an important driving force to overcome the mass transfer resistance of all of the molecules between the aqueous and solid phase, the Fig.1 plots the percentage of dye removal versus the initial dye concentration of the adsorbents. While increasing the initial dye concentration from 50.0 to 250.0 mgL^{-1}, the percentage of dye ion removal by the ALPNC decreased from 85.57% - 46.42%, 90.54% - 49.36% and 91.37% - 71.36% respectively, the percentage removal of the dye decreased slowly in the concentration range of 50-250 mgL^{-1}, but reduced rapidly from 50 to 150 mgL^{-1} dye removal is highly concentration dependent at higher concentrations. This can be explained by the fact that the adsorbent has a limited number of active sites that become saturated above a certain concentration. At low dye concentrations, the ratio of surface active sites to the total MG dye in the solution is high and hence all MG dye may interact with the active functional groups on the surface of the carbon and be removed from the solution. However, with increased dye concentrations, the number of active adsorption sites is not enough to accommodate the MG dye. Therefore, the initial dye concentration was fixed at 50.0 mg L^{-1} in the following experiments [9].

3.3 Effect of adsorbent dose

Five different adsorbent dosages were selected ranging from 0.010 to 0.250 g while the MG dye concentration was fixed at 50 mg/L. The results are presented in Fig. 2. It was observed that percentage of MG dye ion removal increased with increase in adsorbent dose. Such a trend is mostly attributed to an increase in the sorptive surface area and the availability of more active binding sites on the surface of the adsorbent. This may be due to the decrease in total adsorption surface area available to MG dye ion resulting from overlapping or aggregation of adsorption sites. Thus with increasing adsorbent mass, the amount of MG dye ion adsorbed onto unit mass of adsorbent gets reduced, thus causing a decrease in q_e value with increasing adsorbent mass concentration. Furthermore maximum MG dye removal (85%) was recorded by 0.025 g ALPNC and further increase in adsorbent dose did not significantly change the adsorption yield. This is due to the non-availability of active sites on the adsorbent and establishment of equilibrium between the MG dye on the adsorbent and in the solution [10].

3.4 Effect of initial solution pH:

The pH of an initial dye solution exerts profound influence on the adsorptive uptake of adsorbate molecules, presumably due to its influence on the surface properties of the adsorbent and ionization/ dissociation of the adsorbate molecule, Therefore investigation of the effect of pH on the adsorption process is helpful to determine the optimized operational parameters for application and to reveal the adsorption mechanism [11], Adsorption of MG dye onto Los Pantanos De Villa was carried out to examine the effect of pH (in a range of 2-9) on the removal of ago disperse dye from aqueous solution, As seen in fig 3. Dye removal by all studied adsorbents decreased significantly with increasing pH, especially between pH 2.0 and 7.0, the maximum removal percentages of Chromium onto ALPNC, were 80 to 83% respectively.

3.5 Effect of other ions:

The effect of other ions like Cl^- on the adsorption process studied at different concentrations. The ions added to 50mg/L of MG dye solutions and the contents were agitated for 60 min at 30

°C. The results had shown in the (fig.4) reveals that low concentration of Cl^- does not affect the percentage of adsorption of dye on activated ALPNC, because the interaction of Cl^- at available sites of adsorbent through competitive adsorption is not so effective. This is so because ions with smaller hydrated radii decrease the swelling pressure within the sorbent and increase the affinity of the sorbent for such ions [12].

3.6 Effect of Temperature:

It is well known that temperature plays an important role in the adsorption process. The removals of MG dye were shown in table 2 at 30,40,50,60 °C respectively. The MG dye removal increase rapidly from 303K to 333K, this result suggests that the experimental temperature had a greater effect on the adsorption process implying that the surface coverage increased at higher temperatures. This may be attributed to the increased penetration of MG dye inside micro pores or the creation of new active sites at higher temperatures. This indicates the endothermic nature of the controlled adsorption process. Similar result has been reported in the literature [13].

3.7 Adsorption Kinetic and isotherm models:

3.7.1 Adsorption Isotherms

Adsorption isotherms describe the interaction of adsorbate with adsorbents. The experimental adsorption data of MG dye on the Los Pantanos De Villa were analyzed by Langmuir and Freundlich.

3.7.2 Langmuir Isotherm

The Langmuir adsorption model is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface, with no lateral interaction between the adsorbed molecules [14]. The Langmuir adsorption isotherm has been successfully used in many monolayer adsorption processes, the values are in table 3. The adsorption isotherm data were analyzed by the Langmuir isotherm model in the linearised form,

$$C_e/q_e = C_e/q_{max} + 1/(b\ q_{max}) \qquad (3)$$

Where q_e is the equilibrium adsorption capacity of the adsorbent (mg/g), C_e is the equilibrium MG dye concentration in solution (mg/l), q_{max} is the maximum amount of MG that could be adsorbed on the adsorbent (mg/g) and b is the Langmuir adsorption equilibrium constant (L/mg). 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 by the equation

$$R_L=(1/(1+bCo)) \qquad (4)$$

Where C_o (mg/L) is the highest initial concentration of adsorbent and b (L/mg) is Langmuir isotherm constant. The parameter R_L indicates the nature of shape of the isotherm accordingly [15].

$R_L > 1$	Unfavorable adsorption
$0 < R_L < 1$	Favorable adsorption
$R_L = 0$	Irreversible adsorption
$R_L = 1$	Linear adsorption

The R_L values between 0 to 1 indicate favorable adsorption for all initial concentration (C_o) and temperatures studied. The calculated R_L values are given in table 4. High b values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 155.

3.7.3 Freundlich Isotherm

The Freundlich model can be applied to multilayer adsorption with non-uniform distribution of adsorption heat and affinities over the heterogeneous surface [16]. The experimental data were analyzed by Freundlich isotherm model in the linearised form,

$$\log q_e = 1/n \log C_e + \log K_F \qquad (5)$$

where, K_F is the Freundlich adsorption constant and it is the maximum adsorption capacity of MG dye (mg/g) and n is the constant illustrates the adsorption intensity (dimensionless). The values are presented in table 3 shows the favorability of the adsorption process.

3.7.4 pH optimization

The removal of MG dye at different pH was studied in batch mode. A 50mL of test solution of fixed concentrations was treated with 0.025 g of ALPNC and agitated intermittently for 60 min. The contact time and conditions were selected on the basis of preliminary experiments, which demonstrated that equilibrium was established in 40 min. After this period the solutions then both phases were separated by filtration. The dye content of the filtrate was determined by atomic spectrometry. The Dye concentration retained in the sorbent phase (q_e, mg/g) was calculated by using Eq. (1)

$$q_e = \frac{(C_0 - C_e)V}{m} \qquad (6)$$

Where, C_0 and C_e are the initial and final (equilibrium) concentrations of the dye in solution (M), V the solution volume (L) and m is the mass of Activated Los Pantanos De Villa(g).

3.8 Adsorption Thermodynamics

The thermodynamic parameters for the adsorption of MG dye by Activated Los Pantanos De Villa were determined using the following equations:

$$K_D = q_e/C_e \qquad (7)$$

$$\Delta G^o = -RT \ln K_D \qquad (8)$$

$$\ln K_D = (\Delta S^o/R) - (\Delta H^o/RT) \qquad (9)$$

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 [17]. 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, the negative values of Gibbs free energy change (ΔG^o) obtained for the adsorption of MG dye by Activated Los Pantanos De Villa at various temperatures had shown the spontaneous nature of the adsorption process. The negative values of enthalpy change ($\Delta H°$) obtained for the adsorption of MG dye by Activated Los Pantanos De Villa at various temperatures indicated that the adsorption reactions were endothermic. The positive values of entropy change ($\Delta S°$) for the adsorption of MG dye by Activated Los Pantanos De Villa at various temperatures showed the increased randomness at solid liquid interphase during the sorption processes of MG dye on the adsorbent ALPNC. 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.

The adsorption of MG dye by Activated Los Pantanos De Villas lightly increased when temperature was raised up to 60 °C. 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 slightly increased. It showed that the adsorption processes of MG dye by Activated Los Pantanos De Villa were endothermic reactions and physical in nature which involved the strong forces of attraction between the sorbate-sorbent molecules.

3.9 Kinetic modeling in a batch system

In order to investigate the mechanism of adsorption kinetic models are generally used to test experimental data. Pseudo-first-order and pseudo-second-order equations can be used assuming that the measured concentrations are equal to surface concentrations [18]. The pseudo-first-order rate Lagergren model is:

$$\frac{dq}{dt} = k_1,ads(q_e - q) \qquad (10)$$

Where, q (mg/g) is the amount of adsorbed dyes on the adsorbent at time t and $k_{1,ads}$ (min^{-1}) is the rate constant of first-order adsorption. The integrated form of Eq. (10) is:

$$\log(q_e - q) = \log q_e - \frac{k_1,ads}{2.303} t \qquad (11)$$

q_e the equilibrium sorption uptake, is extrapolated from the experimental data at time t = infinity. A straight line of $\log(q_e - q)$ versus t suggests the applicability of this kinetic model. q_e and k_1,ads can be determined from the intercept and slope of the plot, respectively. The pseudo-second order kinetic model is expressed as:

$$\frac{dq}{dt} = k_2,ads(q_e - q)^2 \qquad (12)$$

Where, k_2,ads (g/mg min) is the rate constant of second-order adsorption. The integrated form of Eq. (12) is:

$$\frac{1}{q_e - q} = \frac{1}{q_e} + k_2,ads\,t \qquad (13)$$

Eq. (13) can be rearranged and linearized to obtain:

$$\frac{t}{q} = \frac{1}{k_{2,ads} q_e^{2}} + \frac{1}{q_e} t \qquad (14)$$

The plot t/ q versus t should give a straight line since second order kinetic model is applicable the q_e and $k_{2,ads}$ can be determined from the slope and intercept of the plot, respectively. It is important to notice that for the application of this model the experimental estimation of q_e is not necessary (table.6).

3.9.1 The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / d_t = \alpha \exp(-\beta q_t) \qquad (15)$$

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. Chien and Clayton [19] assumed $\alpha\beta t >> t$ and by applying boundary conditions $q_t = 0$ at t= 0 and $q_t = q_t$ at t = t Eq.(15) becomes:

$$q_t = 1/\beta \ln(\alpha\beta) + 1/\beta \ln t \qquad (16)$$

Since, MG dye adsorption fits with the Elovich model, a plot of q_t vs. ln(t) yields a linear relationship with a slope of (1/β)and an intercept of (1/β)ln (αβ). 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. This may be due to increase the pore or active site on the ALPNC adsorbent.

3.9.2 The Intraparticle diffusion model

The kinetic results were analyzed by the Intraparticle diffusion model to elucidate the diffusion mechanism [20]. The model is expressed as:

$$q_t = K_{id}\, t^{1/2} + I \qquad (17)$$

Where, I is the intercept and K_{id} is the intra-particle diffusion rate constant. The intercept of the plot reflects the boundary layer effect. Larger the intercept, greater is the contribution of the surface sorption in the rate controlling step. The calculated diffusion coefficient K_{id} values are listed in Table 6. The K_{id} value was higher at the higher concentrations. Intraparticle diffusion is the sole rate-limiting step if the regression of q_t versus $t^{1/2}$ is linear and passes through the origin. In fact, the linear plots at each concentration did not pass through the origin. This deviation from the origin is due to the difference in the rate of mass transfer in the initial and final stages of the sorption. This indicated the existence of some boundary layer effect and further showed that Intraparticle diffusion was not the only rate-limiting step.

It is clear from the Table 6 that the pseudo- second-order kinetic model showed excellent linearity with high correlation coefficient (R^2>0.99) at all the studied concentrations in comparison to the other kinetic models. In addition the calculated q_e values also agree with the experimental data in the case of pseudo-second-order kinetic model. It is also evident from Table 6 that the values of the rate constant k_2 decrease with increasing initial MG dye concentrations. This is due to the lower competition for the surface active sites at lower concentration but at higher concentration the competition for the surface active sites will be high and consequently lower sorption rates are obtained.

3.10 Desorption studies

In order to assess the reusability of chromium-loaded Activated Los Pantanos De Villa biomass desorption experiments were carried out. The effect of strength of desorbing solution (NaOH) on the recovery of MG dye is shown in Fig. 5. It is evident from the above figure that when the strength of the desorbing solution increased from 0.5 to 2.0 M, MG dye desorption percentage increased from 28.5% to 79%. Thus a significant amount of MG dye is being desorbed, which shows that the ALPNC biomass can be effectively reused after desorption.

4. Conclusion

This study is revealed that Los Pantanos De Villa can be used as an alternative adsorbent for MG Dye removal in industrial wastewater due to its efficiency of MG dye adsorption in aqueous solution. The adsorption of MG dye onto ALPNC was affected by pH, adsorbent dosage, and temperature. The MG dye uptake percentage by ALPNC was found to be 83.46% when 0.025 g of adsorbent was agitated with 50mL of MG dye solution of 50 mg/L for 60 min at pH. The adsorption data was fitted well by pseudo-second order kinetic indicating that chemical reaction is involved in the adsorption process. The adsorption process was found to be controlled by three steps of diffusion mechanisms. The temperature equilibrium data fitted well with Langmuir isotherm model and the monolayer adsorption capacity was found to be 212.70 mg/g at 333 K. An increase of Q_m value with the increase of temperature implied that chemisorption occurs in the process. Thermodynamic constants were also evaluated using equilibrium constants from Langmuir isotherm. The negative values of ΔG° indicated the spontaneity of MG dye adsorption process and the positive values of ΔH° and ΔS° showed the endothermic nature. This study illustrated that it is possible to remove MG dye from aqueous solution with Los Pantanos De Villa.

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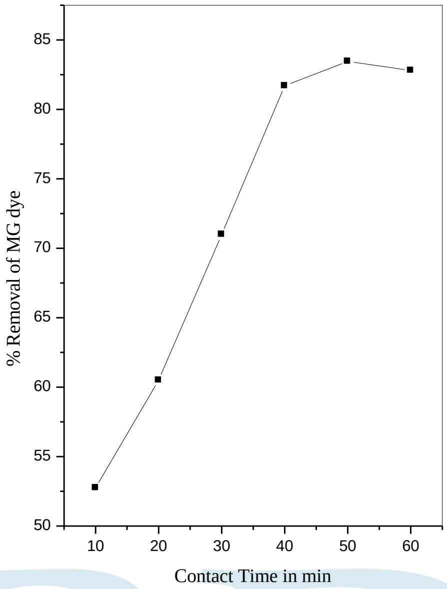

Fig:1-Effect of Contact Time on the Removal of MG dye
[MG]=50 mg/L; adsorbent dose=25mg/50ml; pH-6.5;Temp 30 ^{0}C

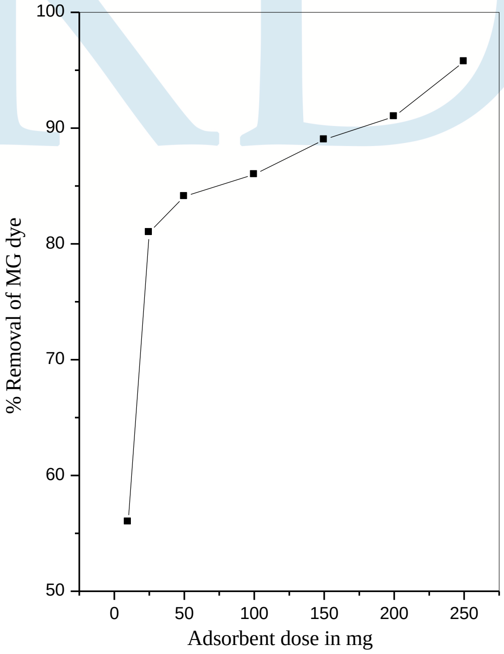

Fig.2-Effect of adsorbent dose on the removal of MG dye
[MG]=50mg/L: Contact time=60 min: pH=6.5: Temp 30^{0}C

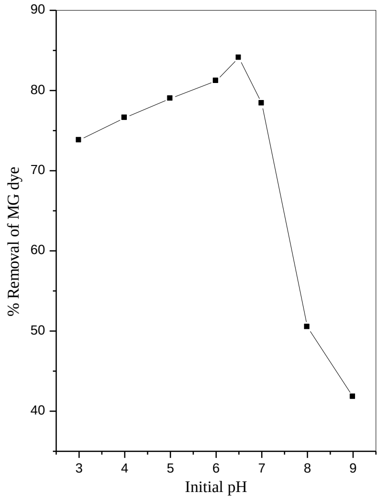

Fig.3-Effect of Initial pH on the removal of MG dye
[MG]=50mg/L: Contact time=60 min: dose=25mg/50ml

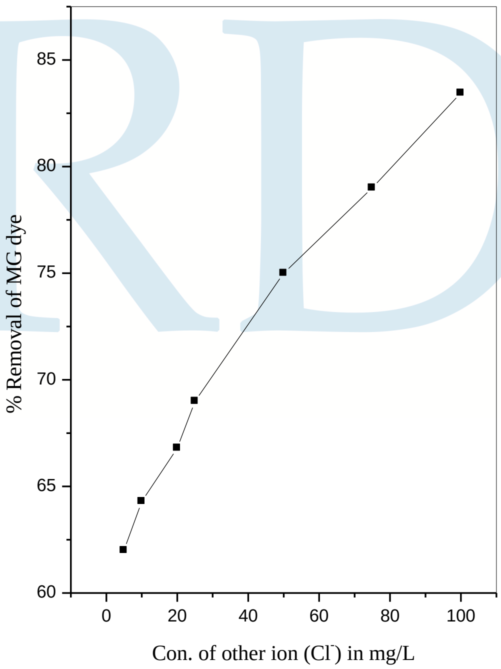

Fig.4-Effect ionic strength on the adsorption of MG dye
[MG]=50 mg/L;Contact time=60 min;Dose=25 mg/50 ml

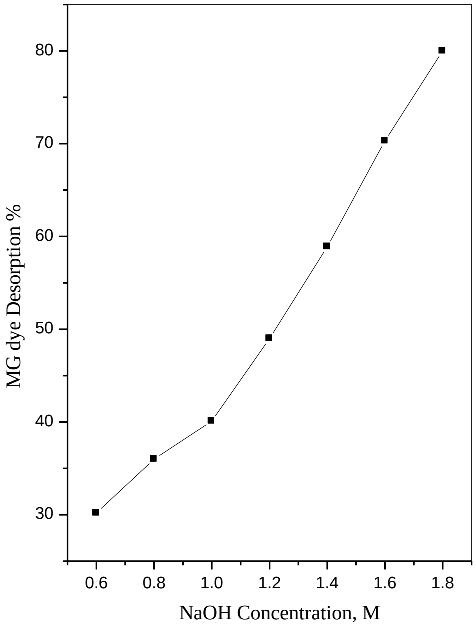

Fig.5- Effect of NaOH Concentration on MG dye desorption

TABLE .2 EQUILIBRIUM PARAMETERS FOR THE ADSORPTION OF MG ON ALPNC ADSORBENT

C_0	Ce (mg / L)				Qe (mg / g)				Dye Removed (%)			
	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	2.93	2.11	2.95	2.957	44.785	45.272	45.688	45.946	85.57	90.544	91.376	91.892
100	8.72	8.76	7.67	6.078	80.413	82.475	85.253	87.244	80.41	82.475	85.253	87.244
150	20.96	19.10	16.90	14.35	107.15	111.74	116.15	120.05	71.43	74.497	77.439	80.037
200	40.70	36.82	16.88	32.86	116.45	122.27	166.15	134.47	58.22	61.139	83.079	67.238
250	65.95	62.28	35.52	56.21	116.05	123.42	178.40	137.56	46.42	49.371	71.360	55.026

TABLE .3 LANGMUIR AND FREUNDLICH ISOTHERM PARAMETERS FOR THE ADSORPTION OF MG ON ALPNC

TEMP. (C°)	Langmuir Parameter		Freundlich parameter	
	Q_m	b	K_f	n
30°	115.404	0.2210	3.7951	3.0911
40°	153.516	0.2211	4.8733	3.1851
50°	217.610	0.0908	4.4842	1.9857
60°	148.891	0.2105	5.0665	3.0235

TABLE .4 DIMENSIONLESS SEPERATION FACTOR (RL) FOR THE ADSORPTION OF MG ON ALPNC

(C_i)	Temperature °C			
	30°C	40°C	50°C	60°C
50	0.1541	0.1585	0.2087	0.1205
100	0.0703	0.0525	0.1656	0.0756
150	0.0464	0.0466	0.1200	0.0425
200	0.0470	0.0400	0.0812	0.0389
250	0.0546	0.0307	0.0645	0.0351

TABLE .5 THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF MG ON ALPNC

C_o	ΔG°				ΔH°	ΔS°
	30° C	40° C	50° C	60° C		
50	-5246.99	-5669.04	-6558.76	-6551.41	6.8402	42.808
100	-3357.2	-4200.58	-4211.79	-5303.13	13.524	54.592
150	-2204.93	-2669.59	-3220.89	-3004.50	11.525	51.220
200	-866.614	-1559.30	-42213.23	-1240.51	18.255	67.214
250	-333.156	-66.456	-2231.66	-552.400	15.449	54.325

TABLE.6 KINETICS PARAMETER FOR THE ADSORPTION OF MG ONTO ALPNC

Co	Temp °C	Pseudo Second Order				Elovich Model			Intraparticle Diffusion		
		q_e	K_2	γ	h	α	β	γ	K_{id}	γ	C
50	**30**	50.858	0.0017	0.991	4.7564	19.341	0.1106	0.990	1.5190	0.991	0.2394
	40	52.822	0.0018	0.992	5.0771	24.201	0.1158	0.990	1.5492	0.991	0.2242
	50	51.754	0.0020	0.992	5.4632	30.829	0.1212	0.992	1.5775	0.991	0.2104
	60	52.162	0.0020	0.992	5.4599	29.719	0.1192	0.993	1.5759	0.991	0.2130
100	**30**	83.938	0.0009	0.993	7.9726	28.678	0.0588	0.994	1.4447	0.991	0.2541
	40	95.730	0.0009	0.993	8.4229	33.377	0.0594	0.996	1.4740	0.991	0.2432
	50	96.705	0.0009	0.993	9.4950	43.413	0.0607	0.997	1.5173	0.992	0.2278
	60	99.06	0.0009	0.994	9.8711	44.791	0.0592	0.998	1.5288	0.992	0.2279
150	**30**	139.47	0.0005	0.990	8.999	25.875	0.0394	0.997	1.3267	0.993	0.2909
	40	122.49	0.0005	0.994	10.264	32.843	0.0401	0.996	1.3809	0.995	0.2712
	50	132.56	0.0006	0.995	11.543	40.600	0.0401	0.991	1.4268	0.996	0.2565
	60	136.37	0.0005	0.992	9.8926	45.751	0.0428	0.991	1.4513	0.990	0.2344
200	**30**	153.50	0.0003	0.990	7.1577	15.568	0.0294	0.995	1.0754	0.990	0.3820
	40	156.45	0.0003	0.990	8.1887	18.949	0.0297	0.996	1.1481	0.990	0.3526
	50	160.75	0.0003	0.990	9.3012	22.840	0.0298	0.997	1.2091	0.990	0.3305
	60	164.75	0.0004	0.990	11.073	29.878	0.0304	0.999	1.2824	0.990	0.3026
250	**30**	179.18	0.0001	0.990	5.0234	10.119	0.0241	0.992	0.7540	0.990	0.5072
	40	182.26	0.0001	0.996	5.745	11.601	0.0236	0.993	0.8334	0.906	0.4768
	50	191.15	0.0001	0.997	6.1784	12.557	0.0227	0.994	0.8745	0.990	0.4670
	60	188.62	0.0002	0.999	7.5459	15.596	0.0232	0.998	0.9805	0.991	0.4213