Journal of Advanced Scientific Research
Available online through http://www.sciensage.info
ISSN
0976-9595
Research Article

CHLOROXYLON SWIETENIA ACTIVATED CARBON FOR ADSORPTION OF MALACHITE GREEN FROM AN AQUEOUS SOLUTION BY KINETIC, BATCH ADSORPTION, ADSORPTION ISOTHERMS AND THERMODYNAMIC STUDIES

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ABSTRACT

Dyes are widely used in textile industries. The colorants have one of the most important roles in industrial pollutants. Many methods have been employed for the removal of colorants from industrial pollutants among which, adsorption technique is very suitable due to high efficiency of its use in the large scale. In our research work, the activated carbon prepared from *Chloroxylon Swietenia* Bark has been used for the removal of malachite green dyes from an aqueous solution. The effective parameters like contact time, adsorbent dose, amount of other ions and pH were considered for the adsorption efficiency. Kinetic models like pseudo second order, Elovich and intra-particle diffusion models being used. Morphological study of *Chloroxylon swietenia* Activated Carbon (CSAC) was determined by using Scanning electron microscopy (SEM) and Fourier transforms infrared spectroscopy (FTIR). The values of thermodynamic parameters indicate that adsorption of MG dye on CSAC is physisorption and also showed that the endothermic and spontaneous in nature.

Keywords: Malachite Green, *Chloroxylon swietenia* Activated Carbon, Adsorption isotherm, Kinetic, pH, Adsorbent dose and contact time.

1. INTRODUCTION

Various chemical industries in the world, like textile, paper, pharmaceutical, leather, rubber, plastics, cosmetics, food and printing have been used dyes for colouring their products. The Malachite green dyes are commonly used for dying in cloths, jutes and paper industries that pollute the environment [1-4]. The recent studies found that the oral consumption of the dyes cause toxic and carcinogenicity in aquatic life organisms. Use of these dyes have been banned in many countries but it still being used due to their low cost, readily availability and efficacy, this not only affect aquatic organism but also reduce photosynthetic activity of plants and affects human parts like liver, kidney, skin and lungs [5-7]. Therefore safe discharge of waste water (dyes) from industries is very important.

Malachite green is the one of the extraordinary consuming materials in the dye industries, which is used for cotton and silk painting. There are several methods have been proposed in order to remove dyes from the industrial waste water. Many methods such as coagulation, reverse osmosis, chemical oxidation, and biodegradation and electro dialysis technique have been used for the removal of dyes from aqueous solution as well as industrial waste water [8-10] but they have some limitations such as high cost, high energy requirement, and incomplete colour removal and produce some toxic products that need further treatment. Many sorbents have been used in current years [11]. This adsorption method is found to be cheap and ecofriendly, reusable and biodegradable, easy operation, high surface area, high adsorption capacity. CSAC is commonly used as an adsorbent for removal of dyes.

In aim of these studies, CSAC was used as an adsorbent to the removal of malachite green from aqueous solution under different experimental methods such as batch adsorption technique, adsorbent dose and contact time.

2. MATERIALS AND METHODS

2.1. Preparation of adsorbate for the removal of MG dye onto CSAC

The stock solution was prepared by dissolving required quantity of merk grade Malachite Green dye (MG) in distilled water. The test solutions were prepared from diluting stock solution with different concentrations. The type of concentration of the malachite green dye was determined at 614 nm.

2.2. Reagents and Instruments for the removal of MG dye onto CSAC

The solution of NaOH and Hydrochloric acid were used in the investigation. The UV-Visible double beam spectrophotometer and pH measurements like digital pH meter were employed in adsorption studies.

2.3. Preparation of adsorbent from *Chloroxylon Swietenia*

The raw bark of *Chloroxylon swietenia* tree was collected nearby village of Komapuram in Pudukkottai (District), Tamilnadu, India. The purified tree bark was dried well and charred with calculated quantity of concentrated H_2SO_4, which was maintained at 260°C for 12 hours. Thereafter, the resultant activated carbon was thoroughly washed with the excess quantity of distilled water followed by drying at 150°C for one hour. It was soaked in 5 % sodium bicarbonate and allowed to stand in a day to removal of any residual acid [12]. The carbonized fabric was heated at 1100°C for six hours in a muffle furnace. Finally the dried powder was sieved with help of a mesh.

2.4. Batch Adsorption Technique

Batch adsorption technique was experimentally done by using 50 ml aqueous dye solution of different initial concentrations in Erlenmeyer 250 ml flasks. The tests were determined at different temperatures between 30 to 60°C. The pH for the removal of MG onto CSAC was studied at the pH of 3 to 9 with the concentration of dye solution. The pH values of initial dye solution (50mgL^{-1}) have been adjusted using 0.1M HCl or NaOH solution. CSAC (0.0250g) was mixed with dye solution and agitated for sample until equilibrium was obtained. After the agitation, dye solution was withdrawn from the shaker at different time intervals the ranges between 10 to 65 minutes and centrifuged at 120 rpm for 10 minutes.

The removal percentage of MG dye was determined by the following equation 1and 2 [13].

$$Percentage\ removal\ of\ MG = \left(\frac{C_0 - C_t}{C_0}\right) \times 100 \ldots\ldots 1$$

$$Q = \frac{C_i - C_t}{m} \times V \ldots\ldots 2$$

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

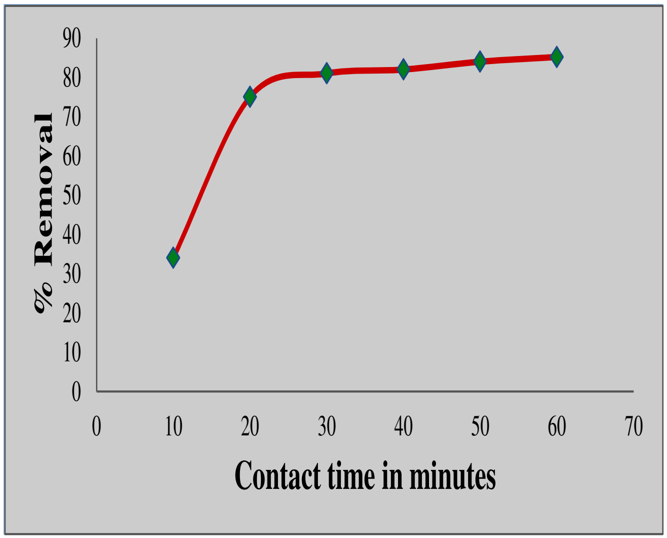
3. RESULTS AND DISCUSSION

3.1. Contact time for the removal of MG dye onto CSAC

The effect of contact time for MG dye adsorption onto CSAC was studied at different time intervals. The percentage removal of MG dye onto CSAC at 10 to 30 minutes and the percentage removal of MG dye adsorption from 51% to 76% respectively is shows in fig.1. The adsorption data obtained for the removal of MG dye was observed by decrease in concentration of dye solution within the adsorption medium and contact time. The time is necessary to attain the equilibrium for the removal of dye molecules at different concentration between 25-125 mg/L by CSAC from an aqueous solution was established to be about at 60 minutes.

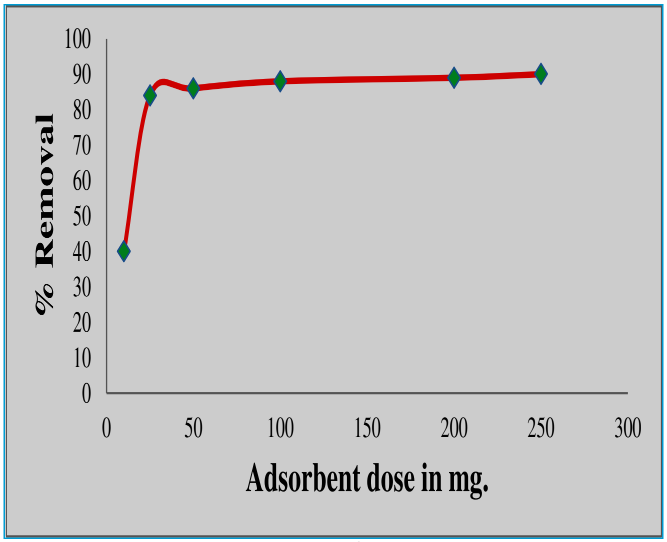
3.2. Adsorbent dose for the removal of MG dye onto CSAC

The effect of different adsorbent dose was studied by employing between the ranges of 25, 50, 100,200 and 250 mg. Adsorbant dooses were agitated with 50 ml of dye solution. The distinctive adsorbent dosages onto the percentage removal of dyes ranges from 0.025 to 0.250g were studied. When an adsorbent dosages increases, the percentage removal of dye increases. The extended adsorption is due to the increase of active sites on surface of the adsorbent [14, 15]. The Percentage removal of dye was maximum at 20 mg/L and adsorption dosage 0.025g/50ml, which is shown in fig.2. The graph specified that increase of adsorption percentage as an adsorbent dosage increases to a certain point. It is due to availability of active sites on the surface area of adsorbent and it attains an equilibrium due to movement of adsorbate from bulk liquid to the surface of adsorbent [16,17].



{[MG] = 25mg/L; Temperature 30°C; Adsorbent dose = 0.025g/ 50mL}

Fig. 1: Contact Time for the removal of MG dye

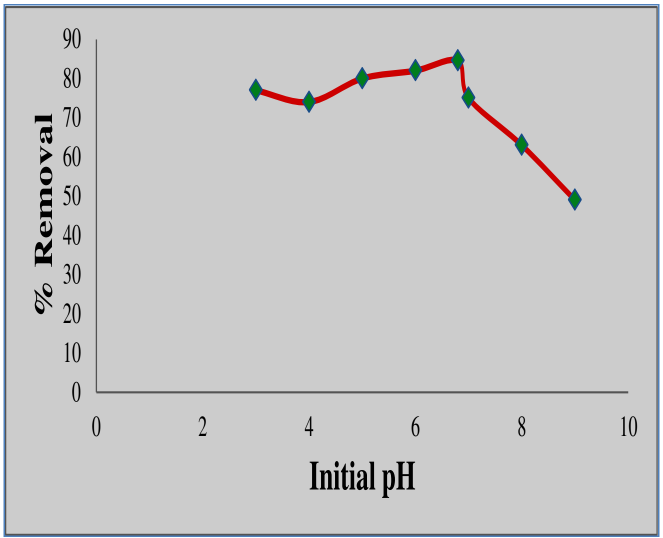


{[MG] = 25mg/L; Temperature 30°C; Contact time = 60 min.}

Fig. 2: Adsorbent doses for the removal of MG dye.

3.3. The pH parameter for the removal of MG dye onto CSAC

The effect of initial pH was studied in the range of pH from 3 to 9. The percentage removal of MG dye increased around 76% and also increased slowly after pH 6.4 thereafter it slowly decreased up to pH 9.0 as shown in Fig. 3. At lower pH values, the charge on the surface of the CSAC may get positively charged as a result of being surrounded by H_3O^+ ions and thus the competitive effect of H_3O^+ions as well as the electrostatic repulsion between the MG dye and the positively charged active adsorption sites on the surface of the CSAC lead to decrease in uptake of MG dye. At higher pH values, the surface of CSAC may get a negative charge leading to an increase in dye uptake due to the electrostatic forces of attraction [18].



{[MG]=20mg/L; Temperature 30°C; Adsorbent dose=0.025g/ 50mL.}

Fig. 3: Effect of Initial pH parameters for the removal of MG dye onto CSAC

3.4. Isotherm Models for Adsorption Studies

3.4.1. a) Freundlich adsorption isotherm for the removal of MG dye

Freundlich adsorption isotherm is derived from the assumption that the adsorption sites are distributed exponentially with respect to heat of adsorption. This adsorption isotherm is expressed by the following equation.

$$q_e = K_F C_e^{1/nF} \ldots\ldots\ldots\ldots\ldots\ldots \quad 3$$

It can be linearized

$$\ln q_e = \ln K_F + \frac{1}{nF}\ln C_e \ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

Where q_e is the amount of dye adsorbed at equilibrium (mg/g) and C_e is the concentration of dye in the aqueous phase at equilibrium (ppm). K_F (L/g) and 1/nf are the Freundlich constant related to adsorption capacity and adsorption intensity, respectively.

The Freundlich constants K_F–and 1/nF were calculated from the slope and intercept of the $\ln q_e$ Vs $\ln C_e$ plot and the model parameters are shown in table 1and 2. The magnitude of K_F showed that CSAC had a high capacity for dye adsorption from an aqueous solution studied [19]. The Freundlich exponent n_f should have values in the range of 1 and 10 (i.e., 1/ n_f <1) to t be considered as favorably adsorbed by CSAC is shown in the following fig. 4.

3.4.2. b) *Langmuir adsorption isotherm for the removal of MG dye*

Based on the assumption of Langmuir adsorption isotherm, the adsorption sites are having equal affinity to the adsorbate [18, 19]. The linear form of Langmuir adsorption isotherm is given as:

$$\frac{C_e}{q_e} = \frac{1}{q_m KL} + \frac{C_e}{q_m} \quad \text{.........................}5$$

Where q_e is the amount of dye adsorbed at equilibrium (mg/g), C_e is the concentration of dye in the aqueous solution in equilibrium (ppm), q_m is the maximum dye uptake (mg/g) and K_L is the Langmuir constants related to adsorption capacity and the energy of adsorption (mg/g). A linear plot of C_e/q_e Versus C_e was employed to determine the value of q_m and K_L as given in Fig. 5 and the data obtained was given in the table 2. The model predicted a maximum value could not be reached in the experiments. The value of K_L decreased with an increase in the temperature. A high value of K_L indicates the high adsorption affinity. The Langmuir isotherm in term of dimensionless constant separation factor or equilibrium parameter (R_L) is defined in the following equation.

$$R_L = \frac{1}{1 + KLC_0} \dots\dots\dots\dots\dots\dots 6$$

Where C_0 is the initial dye concentration (ppm)

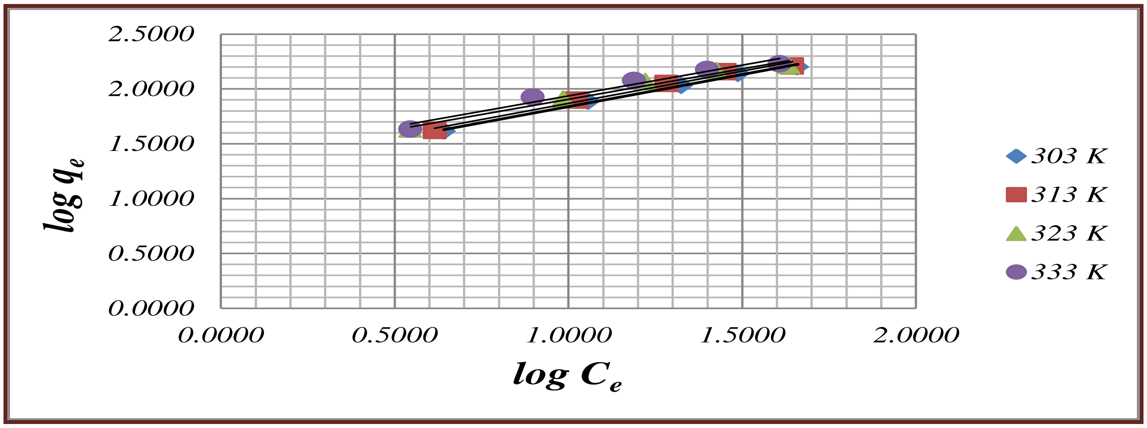


Fig. 4: Freundlich adsorption isotherms for the removal of MG dye

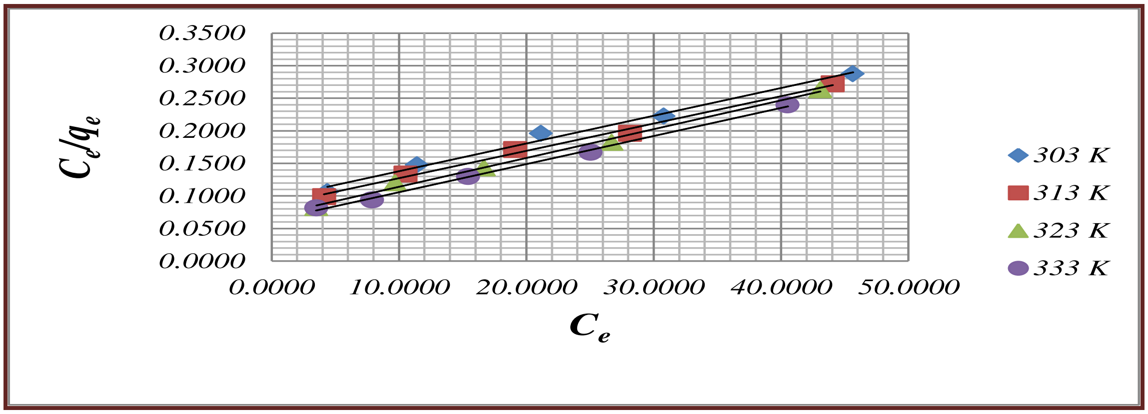


Fig. 5: Langmuir isotherms for the removal of MG dye

The values of dimensionless separation factor (R_L) for dye removal were calculated at different concentrations and temperature. As given in table 3, at all concentrations and temperature tested the values of R_L for dye adsorptions onto the CSAC were less than one and greater than zero that indicates favourable adsorption.

Based on the Langmuir adsorption isotherm, sufficient number of adsorption sites are found onto the CSAC and these adsorptive sites are fully covered by monolayer of the adsorbate thereafter no further adsorption takes place [20, 21]. The fact that the Langmuir adsorption isotherm fits the experimental data well may be due to homogeneous distribution of active sites onto the CSAC surface of the adsorbent from the Langmuir equation assumes that the adsorbent surface is energetically homogeneous.

3.4.3. *c) Temkin Adsorption Isotherm*

The temkin adsorption isotherm assumes that the heat of adsorption decreases linearly with the sorption coverage due to adsorbent-adsorbate interactions [22, 23]. The temkin isotherm equation is given as

$$q_e = \frac{RT}{b_T}\ln(K_T C_e) \ldots\ldots\ldots\ldots 7$$

Equation (7) can be represented in the following form

$$q_e = \frac{RT}{b_T} lnK_T + \frac{RT}{b_T} lnC_e \ \ldots\ldots\ldots\ldots.8$$

Where K_T (L/g) is the temkin isotherm constant, b_T (J/mol) is a constant related to heat of sorption. R is the ideal gas constant (8.314j/mol K) and T is the absolute temperature (K). A plot of q_e verses ln C_e enables the determination of isotherm constants K_T and b_T from the slope and intercept, the model parameters are listed in table 2. The temkin isotherm appears to provide a good fit to the MG dye adsorption data, which is shown in Fig. 6.

The adsorption energy in the temkin model, b_T, is positive for MG dye adsorption from the aqueous solution which indicates that the adsorption is exothermic. The experimental equilibrium curve is close to that predicted by temkin model. Consequently, the adsorption of MG dye on CSNC can be described reasonably well by the temkin isotherm.

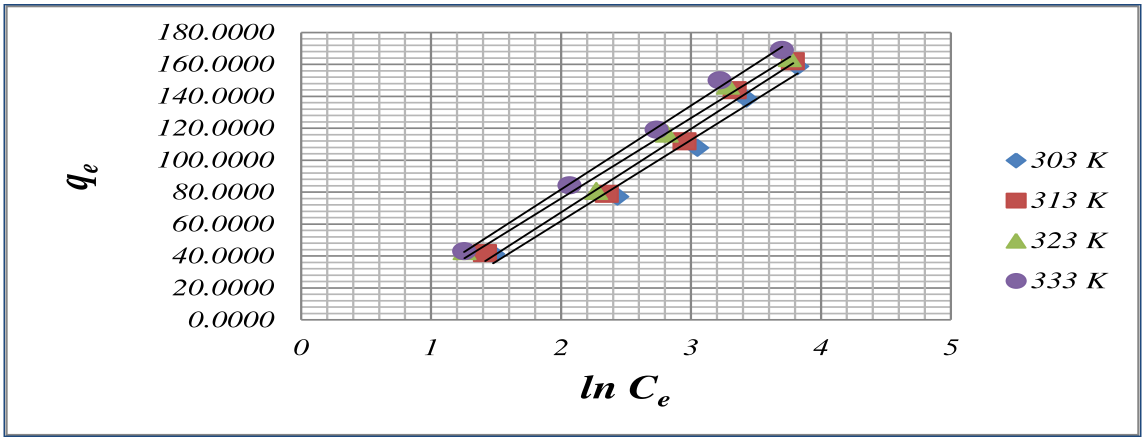


Fig. 6: Temkin isotherms for the removal of MG dye

3.4.4. *d) Hurkins-Jura Adsorption Isotherm*

The hurkins - jura adsorption isotherm can be expressed as [24], [25]:

$$q_e = \frac{\sqrt{A_H}}{B_H + logC_e}\ldots\ldots\ldots\ldots 9$$

This can rearranged as follows:

$$\frac{1}{q_e^2} = \frac{B_H}{A_H} - \frac{1}{A_H} logC_e \ \ldots\ldots\ldots\ldots 10$$

Where A_H (g^2/L) and B_H (mg^2/L) are two parameters characterizing the sorption equilibrium.

The isotherm equation accounts for multilayer adsorption and can be explained by the existence of a heterogeneous pore distribution. The Hurkins-Jura isotherm parameters are obtained from the plots of $1/q_e^2$ versus log C_e enables the determination of model parameters A_H and B_H from the slope and intercept, which is shown in fig. 7. The model parameters are given in the table 2.

3.4.5. *e) Halsay Adsorption Isotherm*

The Halsay adsorption isotherm can be given as [26]

$$q_e = \exp\left(\frac{lnK_{Ha} - lnC_e}{n_{Ha}}\right) \ldots\ldots\ldots 11$$

And, a linear form of the isotherm can be expressed as follows:

$$lnq_e = \frac{lnK_{Ha}}{n_{Ha}} - \frac{lnC_e}{n_{Ha}} \ldots\ldots\ldots 12$$

Where K_{Ha} (mg/l) and n_{Ha} are Halsay isotherm constants.

A plot of lnq_e Vs lnC_e, (Fig. 8) enables the determination of n_{Ha} and K_{Ha} from the slope and intercept. This equation is suitable for multilayer adsorption and the fitting of the experimental data to this equation attest the hetero-pores nature of adsorbent. The experimental data and the model predictions are based on the nonlinear form of the Halsay models. The model paramers were listed in table 2. This result also shows that the adsorption of MG dye on CSAC was not based on significant multilayer adsorption. The Halsay model is also not suitable to describe the adsorption of MG dye on CSAC, because this model also assumes a multilayer behavior for the adsorption of adsorbate on adsorbent.

Table 1: Equilibrium parameters for adsorption of MG dyes onto CSAC

MG	Ce (mg / L)				Qe (mg / g)				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
25	4.38725	4.12401	3.5203	3.5096	41.226	41.752	42.959	42.981	82.451	83.504	85.919	85.962
50	11.40685	10.5334	9.6888	7.8992	77.186	78.933	80.622	84.202	77.186	78.933	80.622	84.202
75	21.1311	19.1321	16.6717	15.4468	107.738	111.736	116.657	119.106	71.825	74.491	77.771	79.404
100	30.7845	28.1526	26.7045	25.0491	138.431	143.695	146.591	149.902	69.216	71.847	73.296	74.951
125	45.6274	44.044	43.073	40.515	158.745	161.911	163.855	168.970	63.498	64.764	65.542	67.588

Table 2: Isotherm Models for the adsorption of MG dyes onto CSAC

Model	Constant	Temperature (°C)			
		30	40	50	60
Freundlich	K_f(mg/g) (L/mg)$^{1/n}$	17.898	18.996	22.520	23.728
	n_F	1.7083	1.6988	1.8038	1.7832
	R^2	0.9841	0.9769	0.9702	0.9658
Langmuir	Q_m (mg/g)	235.09	238.14	226.01	231.82
	K_L (L/mg)	0.0445	0.0492	0.0634	0.0688
	R^2	0.9691	0.9730	0.9743	0.9774
Temkin	b_T (J/mol)	49.618	49.722	53.297	52.698
	K_T (L/mg)	0.4581	0.4901	0.6112	0.6409
	R^2	0.9706	0.9948	0.9959	0.9976
Hurkins-Jura	A_H (g^2/L)	-1867.02	-1933.31	-2158.58	-2224.99
	B_H (mg^2/L)	-1.5832	-1.5509	-1.5314	-1.4980
	R^2	0.8717	0.8446	0.8406	0.7845
Halsay	K_{Ha} (mg/L)	138.074	148.670	275.255	283.327
	n_{Ha}	1.7083	1.6988	1.8038	1.7832
	R^2	0.9842	0.9767	0.9889	0.9739

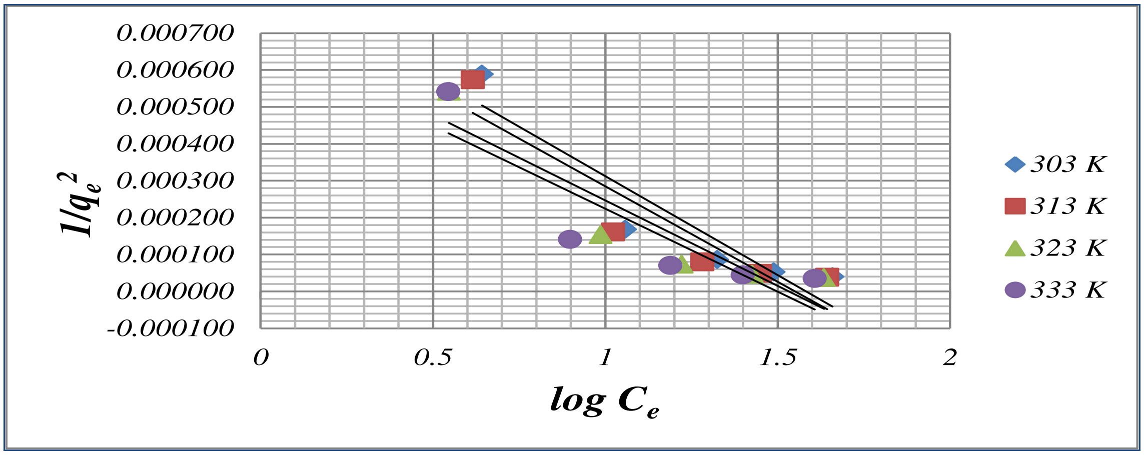


Fig. 7: Hurkins-Jura adsorption isotherms for the removal of MG dye

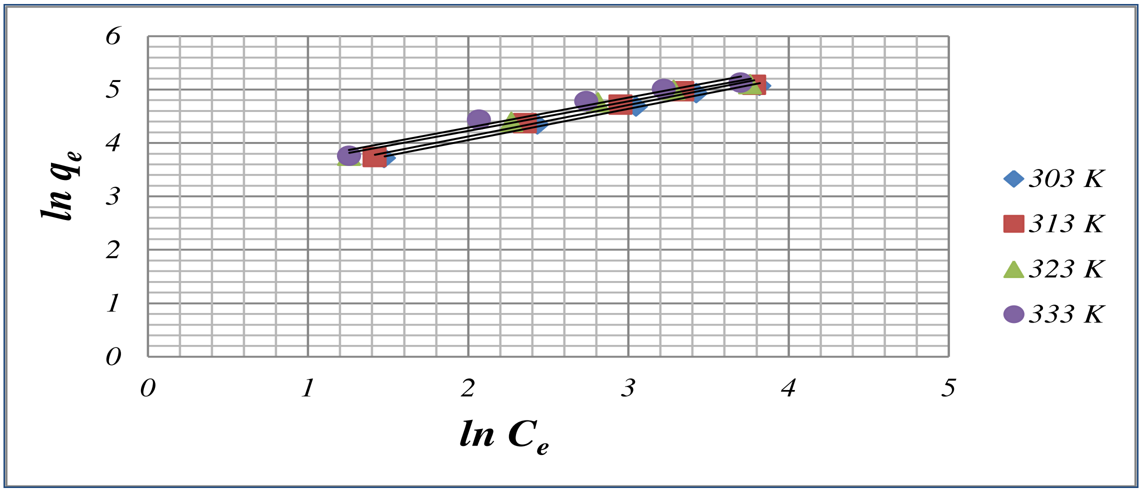


Fig. 8: Halsay Adsorption isotherms for the removal of MG dye

Table 3: Dimensionless separation factor (R_L) for the adsorption of MG dyes onto CSAC

MG	Temperature °C			
(C_i)	30°C	40°C	50°C	60°C
25	0.4734	0.4482	0.3870	0.3676
50	0.3101	0.2888	0.2399	0.2252
75	0.2306	0.2131	0.1738	0.1623
100	0.1835	0.1688	0.1363	0.1269
125	0.1524	0.1397	0.1121	0.1041

3.5. Analytical Techniques for the Removal of MG Dye onto CSAC

3.5.1. a) *Scanning Electron Microscopy*

Scanning Electron Microscopy has been used to investigate the morphological studies of pores structure, shape, size and homogeneity surface of CSAC bio-adsorbent as well as adsorbate particles, which is shown in fig. 9. The surface morphology of CSAC adsorbent of particle size is about 10 μm. The Figure shows that randomness like structure and also indicated that the pores are found onto the CSAC adsorbent [27, 28].

3.5.2. b) *Fourier transform infrared spectrometer*

The FT-IR spectra of fresh *Chloroxylon swietenia* activated carbon after adsorption of dye is shown in the fig. 10. This study is used to determine the characteristic surface of CSAC adsorbent, which is responsible for adsorption of dye. It could be viewed that slight reduced of stretching vibration adsorption bands. The stretching vibration band of OH group is found at 3412 cm^{-1}. It is clearly specified that adsorption of dye occur onto CSAC adsorbent by physical forces of attraction but not by the chemical forces [29, 30].

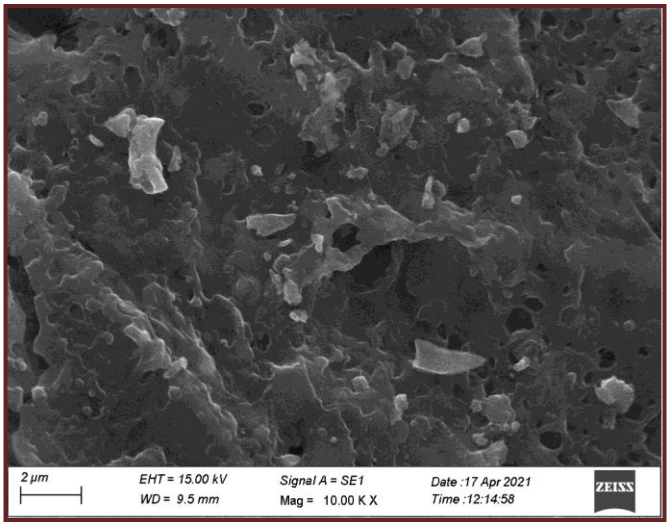


Fig. 9: SEM image of *Chloroxylon swietenia* Carbon (CSAC)

3.6. Adsorption Kinetic Study for the Removal of MG Dye onto CSAC

The mechanism of the adsorption of dyes and rate can be calculated with help of kinetic studies. Adsorption on solid surface can be evaluated by two distinct mechanisms: A. an initial rapid binding of dyes on the surface of the CSAC adsorbent; B. Relatively slow intra particle diffusion. To analyze the removal of dyes, pseudo first order and pseudo second order models were applied. Each of these models was employed for the estimation of surface adsorption reaction rate. It is proposed by Lagergren in 1898. The values of ln (q_e-q_t)

were linearly correlated with t. The plot of ln (q_e-q_t) versus time t should give a linear relationship from which the values of k_1 were calculated from the slope of the plot [31].

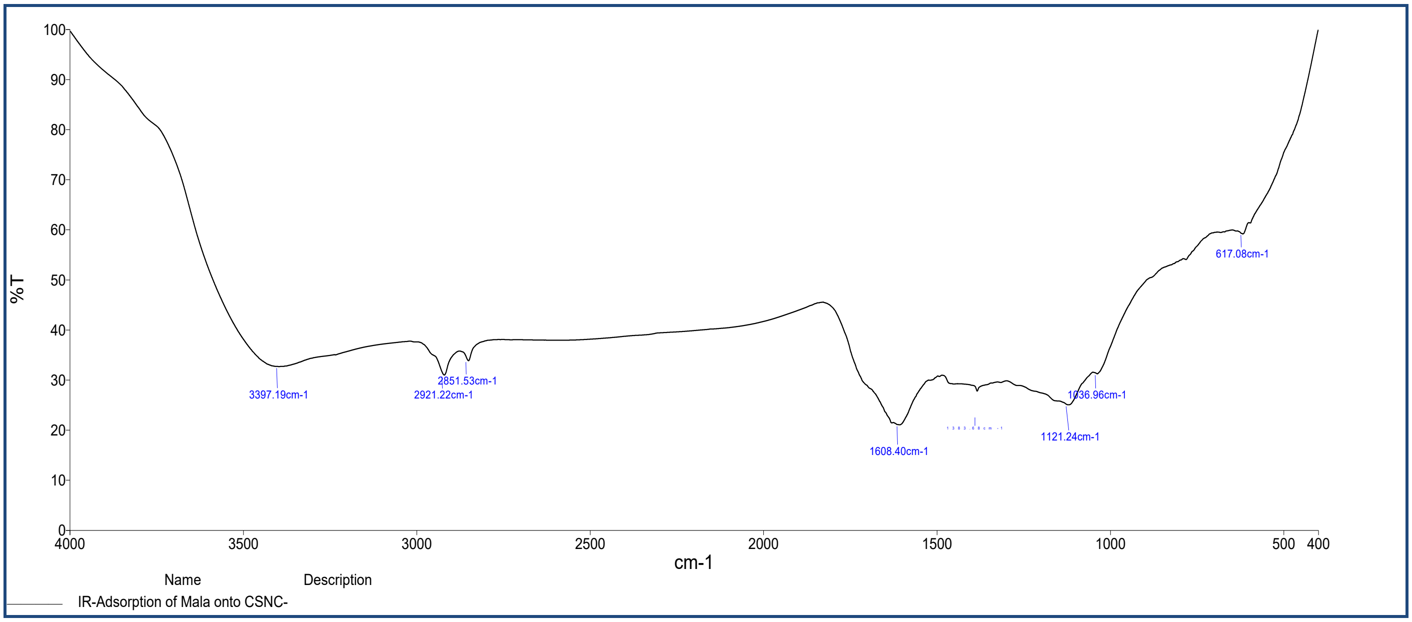


Fig. 10: FTIR Spectra for after adsorption of CSAC

Nonlinear form for pseudo first order is given as:

$$\frac{dq_t}{dt} = k_1(q_e - qt) \text{ ....}13$$

Linear form for pseudo first order is given as

$$\ln(q_e - qt) = lnq_e - k_1t \text{...............}14$$

Nonlinear form for pseudo second order is given as

$$\frac{dq_t}{dt} = k_2(q_e - qt)^2 \text{ ....}15$$

Linear form for pseudo second order is given as

$$\frac{t}{qt} = \frac{1}{k^2qe^2} + \left(\frac{1}{qe}\right)t\text{............}16$$

Where qe and qt refer to the amount dyes adsorbed (mg/g) at equilibrium and at any time, t (min.) respectively and k_1 (1/min.), k_2 (g/mg.min.) are the equilibrium rate constants for the pseudo first order and pseudo second order respectively.

In pseudo- second order kinetic model, the slope and intercept of the t/q_t versus t plot were used to calculate the pseudo-second rate constant, k_2 (g/mg.min). The equilibrium rate constant values (k_2) were given in table 4. In table 4, the value of R^2 (0.999) is related to the pseudo-second order model exposed that dyes adsorption followed this model, that is in agreement with the results obtained nevertheless, pseudo first and second order kinetic models cannot identified the mechanism of diffusion of dyes onto the CSAC adsorbent pores.

Elovich Equation

The general Elovich equation is given by the following formula Equation

$$\frac{dq_t}{dt} = \alpha\, exp(-\beta q_t) \text{ ....}17$$

Where α- is the initial adsorption rate (mg g^{-1} min $^{-1}$) and β is the desorption constant (g/mg). to simplify the Elovich equation of Chien and Clayton (1980) assumed αβt>>t and applying boundary conditions qt=0 at t=0 and q_t=q_t at t=t equation (17) becomes:

$$q_t = \frac{1}{\beta\ln(\alpha\beta)} + \frac{1}{\beta lnt}\text{............}18$$

Since dye adsorption fits with Elovich model, a plot of qt versus ln (t) should yield a linear relationship with a slope of (1/β) and an intercept of (1/β) ln (αβ). Elovich parameters α, β and correlation coefficient (γ) are given in table 4. Experimental data like α, β, and γ were computed from this Elovich model, which indicates that the values of α (initial adsorption rate) increases with temperature similar to that of initial adsorption rate in pseudo second order kinetic models due to increases the active sites on the CSAC bio-adsorbent [32].

3.7. Thermo dynamical Parameters for the Removal of MG Dye onto CSAC

The thermodynamic parameters such as free energy change (ΔG), enthalpy changes (ΔH) and entropy change (ΔS) was determined from this following equations.

$K_c = C_{Ae}/C_e$ .... (19)

$\Delta G^0 = -RT \ln K_c$ .... (20)

$\log K_c = \Delta S^0/2.303R - \Delta H^0/2.303RT$ .... (21)

Where C_e is the equilibrium concentration in solution in mg/L and C_{Ae} is the equilibrium concentration on the sorbent in mg/L and K_c is the equilibrium constant.

The Gibbs free energy for the removal of MG dye onto the adsorbent at all temperatures was obtained from equation (20) and the values are given in table 5. The values of ΔH° and ΔS° were obtained from the slope and intercept for the plot of log K_c against 1/T are given in table 5.

The ΔH values indicate that the nature of adsorption of MG dye on CSAC is physisorption. The positive value of ΔH and negative value of ΔG indicate that the adsorption of MG dye onto CSAC were endothermic and spontaneous in nature. The positive value of ΔS^0 indicates that increased randomness at solid solution interface during the sorption of dye onto CSAC [33, 34].

Table 4: Kinetic parameters for the adsorption of MG dyes onto CSAC

MG	Temp °C	Pseudo second order				Elovich model		
		q_e	k_2	γ	H	α	β	γ
25	**30**	54.8199	8.08E-04	0.9725	2.4280	5.2E+00	8.18E-02	0.9592
	40	53.4154	9.70E-04	0.9772	2.7671	6.4E+00	8.71E-02	0.9592
	50	51.3020	1.42E-03	0.9856	3.7502	1.1E+01	1.02E-01	0.9592
	60	51.2748	1.43E-03	0.9857	3.7709	1.2E+01	1.02E-01	0.9592
50	**30**	92.3091	7.29E-04	0.9691	6.2123	1.9E+01	5.71E-02	0.9058
	40	92.4872	8.46E-04	0.9801	7.2360	2.6E+01	5.97E-02	0.9288
	50	94.8107	9.65E-04	0.9914	8.6789	3.3E+01	5.90E-02	0.9510
	60	93.1026	1.21E-03	0.9811	10.4717	8.1E+01	7.26E-02	0.8810
75	**30**	120.2044	8.80E-04	0.9797	12.7184	1.0E+02	5.69E-02	0.8541
	40	126.2730	9.68E-04	0.9940	15.4352	1.1E+02	5.23E-02	0.9402
	50	134.0054	8.01E-04	0.9951	14.3835	6.9E+01	4.49E-02	0.9677
	60	131.4814	1.23E-03	0.9999	21.2619	1.8E+02	5.29E-02	0.9889
100	**30**	156.6220	8.63E-04	0.9991	21.1678	1.0E+02	3.88E-02	0.9734
	40	161.8903	8.15E-04	1.0000	21.3481	1.1E+02	3.81E-02	0.9905
	50	163.8359	8.84E-04	0.9999	23.7330	1.4E+02	3.90E-02	0.9820
	60	167.0939	8.92E-04	0.9999	24.8976	1.6E+02	3.90E-02	0.9835
125	**30**	180.3584	4.81E-04	0.9677	15.6566	7.3E+01	3.31E-02	0.8589
	40	184.0665	4.74E-04	0.9695	16.0715	7.7E+01	3.26E-02	0.8635
	50	183.9146	5.23E-04	0.9730	17.6929	1.0E+02	3.45E-02	0.8563
	60	190.4475	4.76E-04	0.9667	17.2583	9.0E+01	3.23E-02	0.8425

Table 5: Thermodynamic parameters for the adsorption of MG dyes onto CSAC

MG	ΔG°				ΔH°	ΔS°
	30°C	40°C	50°C	60°C		
25	-3897.6	-4220.3	-4856.7	-5016.9	8.264	40.133
50	-3070.5	-3437.4	-3828.5	-4632.7	12.2321	50.234
75	-2357.4	-2788.7	-3363.1	-3736.1	11.93918	47.171
100	-2041.0	-2438.1	-2711.4	-3034.3	7.81941	32.628
125	-1394.7	-1584.0	-1726.6	-2034.6	4.82700	20.478

4. CONCLUSION

The research work showed that activated carbon made from CSAC is a good efficient adsorbent to the adsorption of Malachite green. The pH plays an important role in removal of MG. The structure, characteristics of a biosorbent and adsorption of MG onto CSAC were studied by SEM analysis and FT-IR Spectroscopy. The positive values of $\Delta H°$ and negative values of $\Delta G°$ clearly showed spontaneity of MG adsorption onto CSAC. The equilibrium data was determined by using adsorption isotherm models such as Langmuir and Freundlich isotherm models. The adsorption efficiency was proved by pseudo second order kinetics. The positive values of ΔS specified endothermic nature for adsorption of MG onto CSAC. The activated carbon prepared from Chloroxylon swietenia tree bark will be used for the removal of toxic dyes as well as metal ions in the treatment of industrial waste water.

Conflict of Interest

Authors have no conflict of interest

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