

Lagenaria siceraria Stem Nano Carbon Adsorption Kinetics and Thermodynamics of Malachite Green Dye

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ABSTRACT

Among the most significant industrial pollutants are dyes, notably in the textile industry. Many techniques have been put forth to remove colour from wastewater, but adsorption is the most widely accepted since it can be applied on a broad scale. The Malachite Green dye has been removed from aqueous settings using this work's application of Modified Activated *Lagenaria siceraria* Stem Nano Carbon (ALSNC). The effects of pH, contact time, starting concentration, and adsorbent quantity were taken into account. Pseudo-first order, pseudo-second order, and intra-particle diffusion kinetic models were among those utilised to examine the mechanism of the adsorption process. Additionally, equilibrium data was fitted to the Radlich-Peterson isotherm model as well as the Langmuir, Freundlich, and Dubinin-Radushkevich, isotherm models. As a result of raising initial dye concentration, pH, and contact duration, the Malachite Green's ability to bind to surfaces was improved, according to the results. pH 9 was the ideal level. Malachite Green dye adsorption had a q_{max} of 15.87 mg/g according to the Langmuir model. The Freundlich isotherm model and the pseudo-second order kinetic model obtained the best fitness when taking into account the values of R^2 (0.999) and 2. This work has shown that ALSNC can be used as a cost-effective and efficient adsorbent for the removal of Malachite Green from aquatic environments.

Key words: Malachite Green, Activated *Lagenaria siceraria* stem Nano Carbon, Kinetics and Thermodynamic studies.

Introduction

Industrial wastewater is regarded as one of the main environmental contaminants. Additionally, because they use coloured materials, textile industries, which are among each nation's basic industries, produce coloured wastewater. Overall, a variety of businesses, including the textile, dyeing, pharmaceutical, food, cosmetics, and healthcare, paper, and leather industries, produce coloured wastewater. Such colours not only alter the aesthetic appearance of the water by changing its colour, but they also block light from accessing the water, interfere

with photosynthesis, harm the aquatic ecology, and threaten a number of aquatic animals. Malachite Green (MG), which is used for cotton and silk painting, is one of the high-consumption dye industry materials. Until recently, a variety of techniques have been suggested to remove colours from industrial wastewater, but adsorption has gained the most acceptance due to its affordability and potential to be applied on a wide scale (Sapci, and Ustun, 2003).

Biological treatment, coagulation, flotation, adsorption, oxidation, and hyper filtration are techniques for colour removal from industrial effluents. Adsorption has been discovered to be superior to

alternative water treatment methods in terms of initial cost, ease of design, convenience of use, and insensitivity to harmful compounds. For the removal of different substances from aqueous solutions, such as dyes, metal ions, and other organic substances, several adsorbents have been utilised, including perlite (Samarghandi, *et al.*, 2012), bentonite, silica gels, fly ash, lignite, peat, silica, etc.

ALSNC, which has a low weight and a fine micro-porous structure (up to 90%) and can be found in several parts of southern Tamil Nadu, India, is one of these natural materials. ALSNC can float in water because to its low density and large specific surface area provided by its thin micro-porous structure. For the elimination of cadmium (Iqbal and Ashiq, 2007), disinfection byproducts, heavy metals, sulphur dioxide, and azo dye, numerous researchers have recently employed activated carbon.

Objectives

Due to the ALSNC's many benefits and accessibility in India, the goal of the current study was to determine how well it removed MG under various experimental circumstances. The initial ALSNC was employed in this study instead of the acid-treated ALSNC due to the initial ALSNC's impurities, limited sorption capacity, and negative charge (Yang and Qiu, 2010). Since ALSNC initially exhibits low sorption capacity, the goal of the acidic treatment of ALSNC was to increase the positive surface charge of the adsorbent and its sorption capacity. In this investigation, MG dye will be removed from aqueous solutions using modified ALSNC.

Materials and Methods

Instruments and Reagents

In order to make stock solution, the necessary amount of MG was dissolved in double-distilled water. Stock solution was diluted to the required concentrations to create the test solutions. At 620nm, the MG concentration was identified. Equipped-Tronics EQ 614A, an Indian digital pH metre, was used to measure pH, and a UV-Vis Double Beam spectrophotometer was used to conduct adsorption tests (Systronics 2203, India). All chemicals were acquired from Scientific Equipment Company in Tiruchirapalli and contained the purest forms of NaOH, HCl, and MG. All solutions were stirred on a hotplate and stirrer (JENWAY, model-1000, India).

Preparing the Adsorbent

In order to get rid of the primary contaminants, *Lagenaria siceraria* Stem was initially collected from a local region in the Nagapattinam district and washed multiple times with de-ionized water. The shell was then soaked for 24 hours in Con. H₂SO₄ (w/v) to carbonise it and increase the porosity of the adsorbent. The produced sample was then well-ground to a fine powder and sieved using a mesh after being washed with de-ionized water numerous times. Finally, this was activated for 12 hours at 1100C in a muffle furnace using activated nano carbon with a fine microporous size of 40 nm as the adsorbent.



Lagenaria Siceraria stem

Adsorption Study

Batch studies were carried out to investigate the impact of crucial factors such pH, contact time, and initial dye concentration on the adsorptive removal of MG. For each experimental run, 50 ml of various dye solution concentrations (ranging from 25 to 125 mg/l) were stirred at 120 rpm with 0.025 g of the adsorbent until equilibrium was reached. The remaining dye concentration in the aqueous solution was examined to evaluate the kinetics, isotherm, and other adsorption parameters after samples were removed at intervals of 10, 20, 30, 40, 50, and 60 minutes. The equilibrium study was carried out at various pH levels 3, 4, 5, 6, 7, 8, and 9 and other equilibrium tests were completed at the ideal pH 6.5 in order to assess the impact of the initial pH on MG adsorption. By adding 0.01 N aqueous solutions of NaOH and HCl, the pH of the solutions was changed.

Equation was used to compute the percentage of dye removal:

$$\% \text{mg Removal} = (C_0 - C_t) / C_0 \times 100 \quad \dots (1)$$

Where, C_0 and C_t represent the initial and time-corresponding dye concentrations in milligrammes per litre, respectively. The following equation was used to determine the equilibrium adsorption capacity once the system had reached equilibrium concentration:

$$q_e = v (C_0 - C_e) / w \quad \dots (2)$$

The initial and equilibrium dye concentrations are represented by C_0 (mg/l) and C_e (mg/l), respectively, in this equation. The volume of the dye solution and the weight of the adsorbent are represented by v (L) and w (g), respectively.

Results

The Effect of pH on the Removal Efficiency

Solution Aqueous chemistry and the surface binding sites of the adsorbents are both impacted by pH. At an initial MG dye concentration of 25 mg/L, an adsorbent dosage of 0.025 g, and a contact period of 60 min, the impact of starting pH on MG adsorption was investigated from pH 3 to 9. There are two potential processes by which the MG dye may bind to the ALSNC adsorbent: (a) an electrostatic contact between the adsorbent and the MG molecule, and (b) a chemical reaction between the MG and the adsorbent. The amount of OH ions in the ideal solution grows together with the pH level. As a result, the ALSNC surface becomes deprotonated, amplifying the negative charge on the surface of the previously used ALSNC. As a result, the electrostatic attractive force between the positively charged MG dye and the adsorbent surface rises, which also enhances the rate of dye absorption (Robinson *et al.*, 2001). As seen in Figure 3, the rate of removal also increased up to pH 6.5 before beginning to decline as the pH of the solution rise from 3 to 9.

The Effect of Contact Time on the Removal of MG Dye

Adsorption phenomena on the adsorbent and diffusion of the adsorbate on the utilised adsorbent are typically laborious processes (Santhy and Selvapathy, 2006). The amount of MG in the adsorption medium decreased during the course of the contact time, which was used to determine the adsorption rate for MG on ALSNC. It was determined that it would take roughly 60 minutes for ALSNC to reach equilibrium before it could begin to remove MG molecules from aqueous solutions at various

concentrations (ranging from 25 to 125 mg/l). As shown in Figure 1, at all of the employed concentrations, the adsorption rate increased along with the length of time the adsorbent was in contact with the adsorbate. The largest rate of MG clearance, as seen in Figure 1, occurred between 10 and 30 minutes. This decline persisted with a lesser slope up to 60 minutes in the remaining concentrations. The system was nearly steady from this point on and did not see significant adsorption for the next 60 minutes. According to removal rate at 25 mg/l of MG ranged from 67.38% to 85.87% of the maximum removal onto ALSNC. For instance, each linear part of the figure corresponds to one of the three stages that the adsorbents displayed. The MG diffusion process to the adsorbent surfaces was attributed to the initial linear part, which was the quickest sorption step. The factionary-order kinetic model confirms this finding. The delayed process of intra-particle diffusion was responsible for the second linear section. The formation of equilibrium comes after the diffusion via smaller pores, which can be viewed as the third step (McKay, *et al.*, 1999). The solute uptake can be related to the active sites on equilibrium time and the surface of the ALSNC may have a significant number of active sites. The increased number of unoccupied sites accessible during the beginning stage may be the cause of the higher sorption rate during the initial period (first 60 minutes). The concentration gradient between adsorbate in solution and adsorbate on adsorbent surface is thereby enhanced. At first, MG sorption tends to increase with this increase in concentration gradients.

The Effect of Initial Concentration on MG Removal Efficiency

At various concentrations of 25, 50, 75, 100, and 125 mg/l, the impact of the initial MG dye concentration on the adsorption effectiveness of the ALSNC was assessed. In the current investigation, the rate of dye removal decreased from 84.8% to 75.9% when the starting concentration increased from 25 mg/l to 125 mg/l. Additionally, the number of open sites on the adsorbent surface shrank as the pollutant concentration in the aquatic environment increased. In other words, the adsorption rate increases when the number of pollutants in the aquatic environment decreases because the adsorbate molecules have a greater probability of reacting with the active sites on ALSNC. Consequently, it can be said that diluting wastewater is one way to increase the percent-

age of dye removal (Dođan *et al.*, 2000).

Adsorption Isotherms

To maximise the design of a sorption system, it is critical to choose the most suitable correlation for the equilibrium adsorption isotherm. The adsorption equilibrium was analysed using the Freundlich, Langmuir, Temkin, Hurkins-Jura, Halsay, Redlich-Peterson, Dubinin-Radushkevich, Jovanovich, and BET isotherm models. At various temperatures and an adsorption duration of 60 minutes, experimental isotherm data were collected.

Freundlich adsorption isotherm

Based on equilibrium sorption on heterogeneous surfaces, the Freundlich adsorption isotherm was developed. This isotherm is derived on the grounds that the distribution of adsorption sites with respect to adsorption heat is exponential. The following equation represents the adsorption isotherm.

$$q_e = K_F C_e^{1/nF} \quad .. (3)$$

Which, can be linearized as

$$\ln q_e = \ln K_F + \frac{1}{nF} \ln C_e \quad .. (4)$$

Where C_e is the concentration of MG dye in the aqueous phase at equilibrium and q_e is the amount of MG dye adsorbed at equilibrium (mg/g) (ppm). The Freundlich constants for adsorption capacity and sorption intensity, respectively, are K_F (L/g) and $1/nF$.

The slope and intercept of the $\ln q_e$ Vs $\ln C_e$ plot were used to determine the Freundlich constants K_F and $1/nF$, and the model parameters are reported in Table 1. The size of K_F indicated that ALSNC has a significant ability to adsorb MG dye from the aqueous solutions under investigation. To be regarded as favourable adsorption, the Freundlich exponent, nF ,

must have values between 1 and 10 (i.e., $1/nF < 1$) (Bereket, *et al.*, 1997). An indication that MG dye is positively adsorbed by ALSNC is a $1/nF$ value less than 1. According to SSE and Chi-square statistics, the Freundlich isotherm did not provide a good fit to the experimental data.

Langmuir adsorption isotherm

According to the Langmuir adsorption isotherm, all sorption sites have an equal affinity for the adsorbate. The linear version of the Langmuir isotherm is given by the expression (Mohamed, 1996):

$$\frac{C_e}{q_e} = \frac{1}{q_m K_L} + \frac{C_e}{q_m} \quad .. (5)$$

Where q_e is the maximum amount of MG dye that can be absorbed (mg/g), q_m is the maximum amount of MG dye that can be absorbed (mg/g), and K_L is the Langmuir constant associated with adsorption capacity and the energy of adsorption (g/mg).

The value of q_m and K_L was calculated using a linear plot of C_e/q_e Vs C_e , and the results were also provided in Table 2. The experiments were unable to reach the maximum value that the model projected. With an increase in temperature, K_L 's value fell. A strong adsorption affinity is indicated by a high K_L value. The equilibrium parameter (R_L), which is described in the following equation, was used by Weber and Chakraborti (Mohan, *et al.*, 2002) to express the Langmuir isotherm.

$$R_L = \frac{1}{1 + K_L C_0} \quad .. (6)$$

where C_0 is the initial concentration of MG dye (ppm). There are four distinct scenarios:

When R_L is greater than 1, the sorption isotherm is unfavourable, linear when R_L is equal to 1,

Table 1. Isotherms parameter for the adsorption of (mg) dye onto ALSNC

Model	Constant	Temperature (°C)			
		30	40	50	60
Freundlich	$K_f(\text{mg/g}) (\text{L/mg})^{1/n}$	11.9	17.779	22.448	23.649
	N	1.4212	1.6481	1.8065	1.7856
Langmuir	Q_m (mg/g)	291.72	243.64	225.01	230.88
	b (L/mg)	0.0273	0.0458	0.0633	0.0687
Radlich-Peterson	G	0.2964	0.3933	0.4465	0.44
	K_R (mg/g)	0.084	0.0562	0.0445	0.0423
Dubinin-	$q_s(\text{mg/g})$	137.82	132.58	132.82	141.25
Radushkevich	$K_D 10^{-4} \text{ mol}^2 \text{ lJ}^{-2}$	1.6169	1.6014	1.5965	1.6086

favourable when RL is between 0 and 1, and irreversible when RL is zero. At various concentrations and temperatures, the values of the dimensionless separation factor (RL) for MG dye removal were computed. The values of RL for MG dye adsorptions on the ALSNC were less than 1 and more than zero at all concentrations and temperatures tested, indicating good adsorption.

The Langmuir isotherm provided a better fit to the adsorption data than the Freundlich isotherm. Since the Langmuir equation presumes that the adsorbent surface is energetically homogenous, it is possible that the homogeneous distribution of active sites on the ALSNC surface is the cause of how well the Langmuir isotherm fits the actual results.

Radlich-Peterson adsorption isotherm

The properties of the Langmuir and Freundlich isotherms are combined into a single equation by the Radlich-Peterson adsorption isotherm, which has three parameters. The following is a description of the generic isotherm equation (Altenor, 2009):

$$q_e = \frac{K_R C_e}{1 + a_R C_e^g} \dots\dots\dots(7)$$

The isotherm’s linear form is represented as follows:

$$\ln \frac{C_e}{q_e} = g \ln C_e - \ln K_R \dots\dots\dots(8)$$

Where g is the exponent between 0 and 1, KR (L/g) and aR (L/mg) are the Radlich-Peterson isotherm constants, and there are two limiting situations: Henry’s law for g = 0 and Langmuir form for g = 1.

The values of KR shown in Table 1 show that the ALSNC’s adsorption capability declined as temperature raised. Additionally, g has a value between 0 and 1, which indicates good adsorption.

Dubinini-Radushkevich adsorption isotherm

Another isotherm equation is the Dubinin-Radushkevich adsorption isotherm. It is presumable that the sorption curve’s characteristic has something to do with the adsorbent’s porosity. The isotherm’s linear form can be written as follows (Mahvi, et al., 2012):

$$\ln q_e = \ln Q_D - B_D \left[RT \ln \left(1 + \frac{1}{C_e} \right) \right]^2 \dots\dots\dots(9)$$

Where BD is the Dubinin-Radushkevich constant

(mol²/kJ²) and QD is the maximum sorption capacity (mol/g). The isotherm constants BD and QD can be calculated from the slope and intercept using a plot of lnqe Vs RTln (1+1/Ce), as illustrated in Fig. 10.

Adsorption Kinetics

Based on kinetic studies, the rate and mechanism of the adsorption process can be clarified. Two different methods can be used to explain dye adsorption on solid surfaces: (2) Relatively sluggish intra-particle diffusion; (1) an initial fast binding of dye molecules on the adsorbent surface. The pseudo-first-order, pseudo-second-order, and intra-particle diffusion models were used to assess the dye’s adsorption kinetics (Panuccio, et al., 2009). The equations for each of these models’ linear modes are shown below

Kinetic Models and Their Linear Forms

Model	Nonlinear Form	Linear Form	Number of Equation
Pseudo-first-order	$dq_t/dt = k_1(q_e - q_t)$	$\ln (q_e - q_t) = \ln q_e - k_1 t$	(10)
Pseudo-second-order	$dq_t/dt = k_2(q_e - q_t)^2$	$t/q_t = 1/k^2 q_e^2 + (1/q_e)t$	(11)

Where k₁ (1/min), k₂ (g/mg.min) are the equilibrium rate constants of the pseudo-first order and pseudo-second order models, respectively, and qe and qt refer to the quantity of MG dye adsorbed (mg/g) at equilibrium and at any time, t (min), respectively.

A straightforward kinetic model called the pseudo-first order model, developed by Lagergren in 1898, is used to calculate the rate of the surface adsorption reaction. There was a linear correlation between the values of ln (qe - qt) and t. The values of k₁ were calculated from the slope of the plot by ln (qe - qt) vs. t, which should show a linear relationship. The first-order equation of Lagergren is typically relevant for the initial stage of the adsorption processes, but it frequently does not fit well with the complete range of contact duration (Kaplan et al., 2010).

The slope and intercept of the t/qt Vs t plot were used to determine the second-order rate constant, k₂, in the pseudo-second order model. The values of the equilibrium rate constant (k₂). The pseudo-second order model’s R² value of 0.999 indicated that MG dye adsorption followed these models. However,

the mechanism of dye diffusion into the adsorbent pores cannot be determined using pseudo-first order or pseudo-second order kinetic models.

Simple Elovich Model

The straightforward Elovich model is represented as follows:

$$q_t = \alpha + \beta \ln t \dots\dots\dots(12)$$

Where q_t is the quantity that has been adsorbed at time t , and α and β are constants discovered by experimentation. The simple Elovich kinetic should be applicable if q_t is plotted against $\ln t$ and a linear connection is obtained. The simple Elovich kinetics of MG dye on to ALSNC are depicted in the following figure for a range of starting concentrations (25, 50, 75, 100, and 125 mg/l), volume 50 ml (each), adsorbent dosage 0.025g, temperature 28 °C, and pH 6.5.

Intra-Particle Diffusion Model

Adsorption on a porous adsorbent typically involves several steps. The experimental results were compared to the intra-particle diffusion model in order to analyse the mechanism of MG dye adsorption by ALSNC. Adsorption at the surface of pores, intra-particle diffusion, and mass transfer over the external film of liquid surrounding the particle make up the three processes that make up the adsorption mechanism of the adsorbate onto the adsorbent. The process’s overall speed is determined by which phase is the slowest. Using the intra-particle diffusion model provided in the equation, the potential for intraparticle diffusion resistance that could impact the adsorption is investigated (Moraci and Calabro, 2010).

$$q_t = K t^{1/2} + I \dots\dots\dots(13)$$

Where, I is the intercept and K is the intra-particle diffusion rate constant. To examine the idea of intra-particle diffusion serving as the rate-determining step, a plot of q_t against $t^{1/2}$ is created. From the experimental data, a two stage adsorption mechanism has been discovered, with the first stage being quick and the second stage being slow. The multi-linear and off-center shape of the q_t against $t^{1/2}$ plot indicates that more than one process has had an impact on the adsorption. As a result, the first section of the plot represents external mass transfer, whereas the second part represents intra-particle or pore diffusion.

Thermodynamic treatment of the sorption process

The following equations can be used to determine the thermodynamic parameters such as free energy, enthalpy, and entropy changes in order to assess the viability of the adsorption process.

$$K_c = C_{Ae} / C_e \dots\dots\dots(14)$$

$$\Delta G^0 = -RT \ln K_c \dots\dots\dots(15)$$

$$\text{Log } K_c = \Delta S^0 / 2.303R - \Delta H^0 / 2.303RT \dots\dots\dots(16)$$

Where, K_c is the equilibrium constant, C_e is the equilibrium concentration in solution in mg/l, C_{Ae} is the equilibrium concentration on the sorbent in mg/l, and both are expressed in mg/l. For the adsorption of MG onto biomass at all temperatures, the Gibbs free energy (ΔG^0) was derived from Eq. 15. The values of ΔH^0 and ΔS^0 are likewise reported. Were derived from the slope and intercept of the plot of $\log K_c$ against $1/T$ (Figure not shown).

The values of activation energy (E_a) and sticking probability (S^*) were computed from the experimental data to support that physical adsorption is the major process. They were estimated using the following (θ) surface coverage-related modified Arrhenius type equation [18]:

$$\theta = \left(1 - \frac{C_e}{C_i} \right) \dots\dots\dots(17)$$

$$S^* = (1 - \theta)_e \frac{-E_a}{RT} \dots\dots\dots(18)$$

The adsorbate/adsorbent system under discussion affects the sticking probability, S^* , which is a function of the system’s temperature and is reliant on the condition $0 < S^* < 1$.

To makes it abundantly evident that the reaction is spontaneous in nature because ΔG^0 values are negative at all investigated temperature. The sorption’s endothermic character is confirmed by another positive ΔH^0 value. The affinities of the adsorbents for the MG dye are indicated by the positive value of ΔS^0 . The adsorption of MG dye onto biomass was found to have an E_a value of 217.59 kJ mol⁻¹. The endothermic character of the adsorption process is indicated by the positive value of E_a , which is consistent with the positive values of ΔH^0 . The results demonstrate that physisorption is the sorption process at work, with the chance of the MG dye adhering to the surface of biomass being quite high as $S^* \ll 1$.

Error Analysis

The optimization process in single-component iso-

therm research necessitates the definition of an error function in order to assess the fit of the isotherm to the experimental equilibrium data. R^2 can only be used to solve the isotherm equation's linear forms; it cannot, however, be used to correct inaccuracies in isotherm curves. The Chi-square test was applied in this investigation. Essentially, the Chi-square test statistic is the sum of the squares of the differences between experimental data and data calculated from models, with each squared difference being divided by the corresponding data calculated from models (Yavuz and Aydin, 2006). The mathematical equivalent of this statement is:

$$\chi^2 = \sum_i=1^m (q_{e,exp} - q_{e,calc})^2 / q_{e,exp} \dots\dots\dots(19)$$

Where $q_{e, calc}$ is the equilibrium capacity calculated from the model (mg/g) and $q_{e,exp}$ is the experimental data of the equilibrium capacity (in mg/g). Therefore, in order to validate the best-fit iso-

therm for the adsorption of MG on ALSNC, it is important to evaluate the data set using the Chi-square test. The Freundlich isotherm model provides the best goodness of fit among the applied isotherm models, according to the values of R^2 .

Evidence of Adsorption

Figures 5(a) and 5(b) show the FT-IR spectra of unprocessed ALSNC carbon and carbon after MG dye adsorption. It was evident that the stretching vibration adsorption bands had slightly decreased. This demonstrates unequivocally that MG dyes adhere to the adsorbent through physical forces rather than chemical synthesis. Figures 6(a) and 6(b) depict the XRD graphs of carbon adsorbed with MG dyes and ALSNC carbon, respectively. After the adsorption of MG dyes, the strength of the highly structured peaks is marginally reduced, indicating the presence of a highly organised crystalline structure in the raw

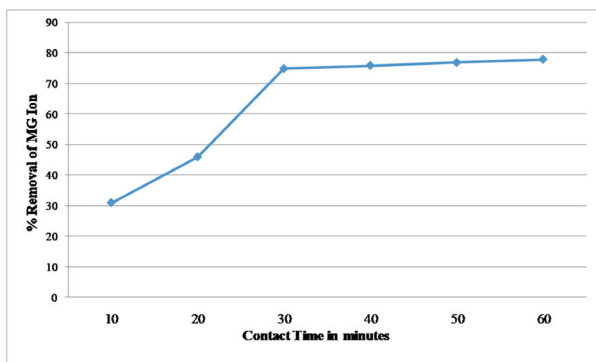


Fig. 1. Effect of Contact time on the Removal of MG ion [MG]= 50 mg/l; Temperature 30°C; Adsorbent dose = 0.025 g/50 ml.

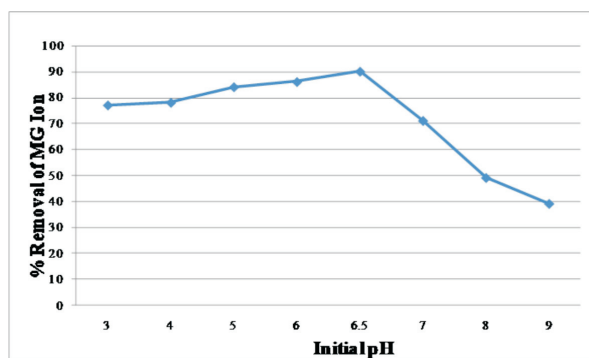


Fig. 3. Effect of Initial pH on the Removal of MG ion [MG]= 50 mg/l; Temperature 30°C; Adsorbent dose = 0.025 g/50 ml.

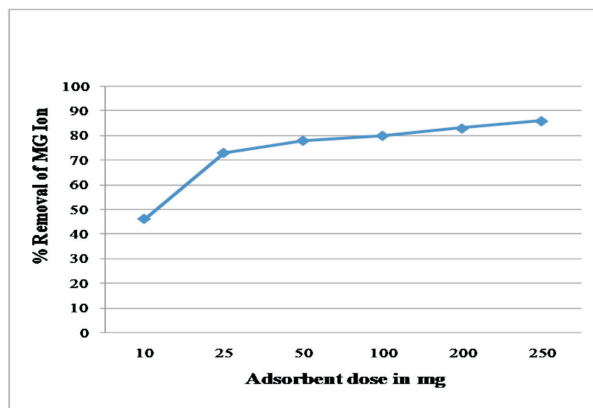


Fig. 2. Effect of Adsorbent dose on the Removal of MG ion [MG]= 50 mg/l; Temperature 30 °C; Contact Time = 60 min.

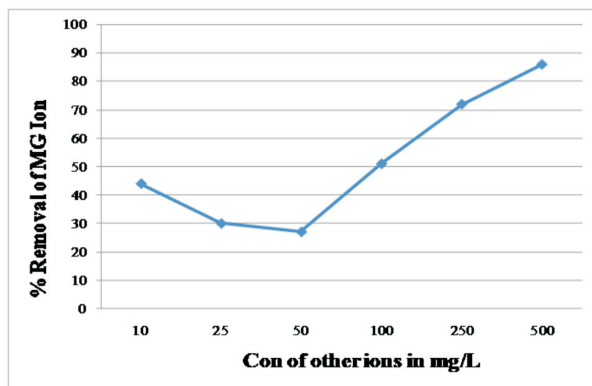


Fig. 4. Effect of Concentration of other ions on the removal of MG ion [MG]= 50 mg/l; Contact Time 60 min.; Adsorbent dose =0.025g/50 ml

Fig. 5(a,b). FT-IR spectrum of ALSNC

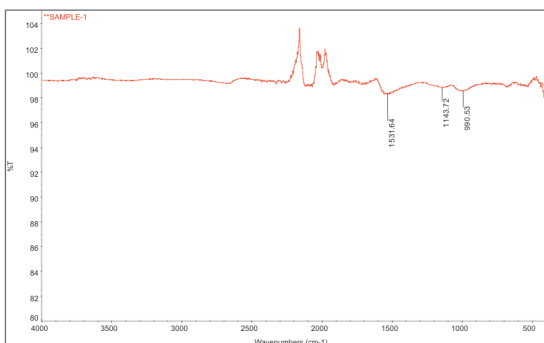


Fig. 5(a) Before Adsorption

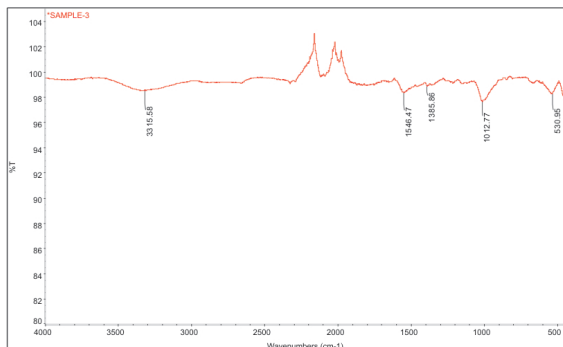


Fig. 5(b) After Adsorption

Fig.6 (a,b) XRD pattern of ALSNC

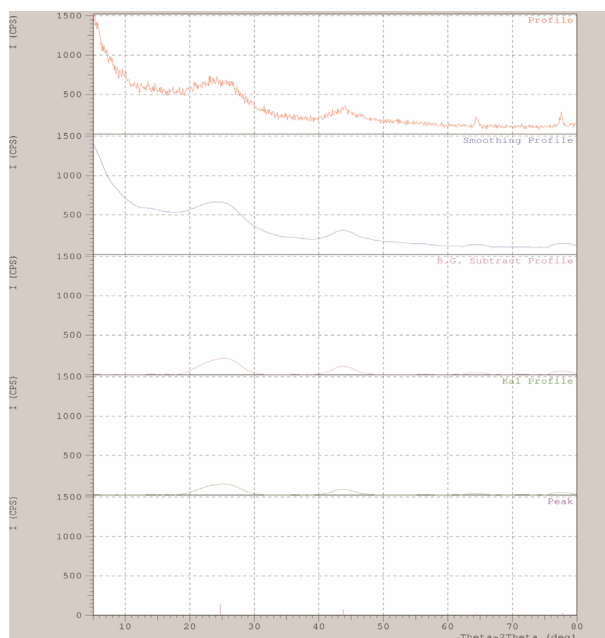


Fig. 6(a) Before Adsorption

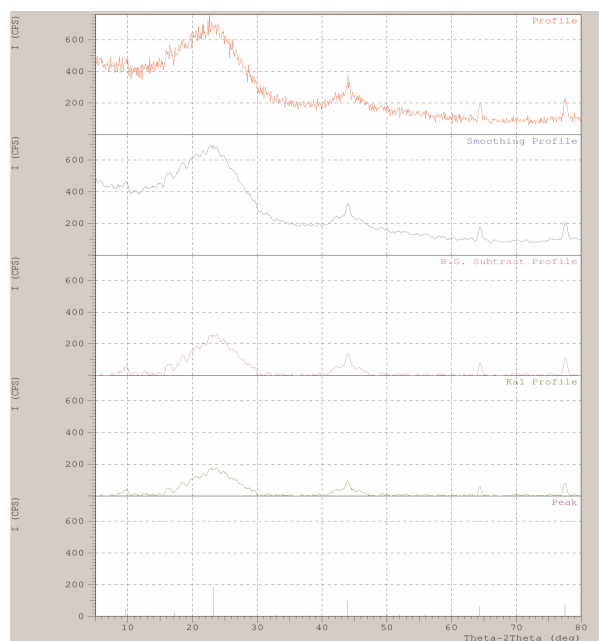


Fig. 6(b) After Adsorption

ALSNC carbon. This has been linked to the MG dyes' physisorption-mediated adsorption on the top layer of the carbon surface's crystalline structure. Figures 7(a) and 7(b) of the SEM micrograph of the ALSNC-derived ALSNC show its uneven surface and significant porosity. These carbonaceous materials frequently have enormous macropores that let adsorbates into the microporous system. At such magnification, the ALSNC particles showed rough areas of surface with clearly visible micropores. This metallic element was not distributed uniformly across the surface of the carbon because the majority of the minerals in biomass are not lost during the pyrolysis procedure and stay on the ALSNC struc-

ture (Alkan and Dođan, 2001).

Discussion

The results of the current study, which examined the effectiveness of ALSNC as a low-cost adsorbent, showed that ALSNC was a suitable adsorbent for eliminating MG from aquatic habitats. Another important factor in eradicating the MG is pH. The results of the current study also demonstrated that as contact duration raised the primary concentration of the dye and the dose of the desired adsorbate both increased. The Langmuir, Freundlich, Radlich-Peterson adsorption isotherm, and Dubinin-

Fig.7(a,b) SEM micrograph of ALSNC

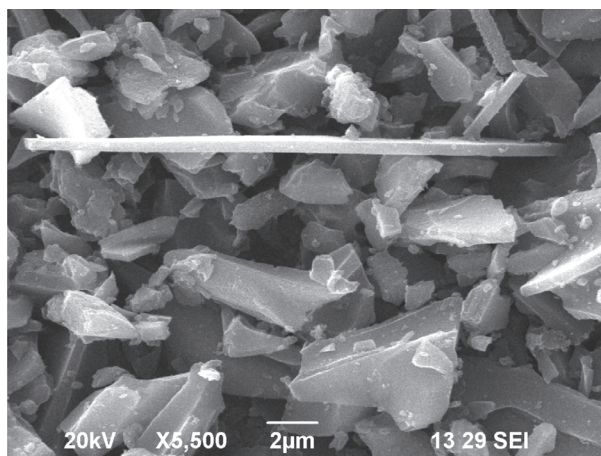


Fig. 7(a) Before Adsorption

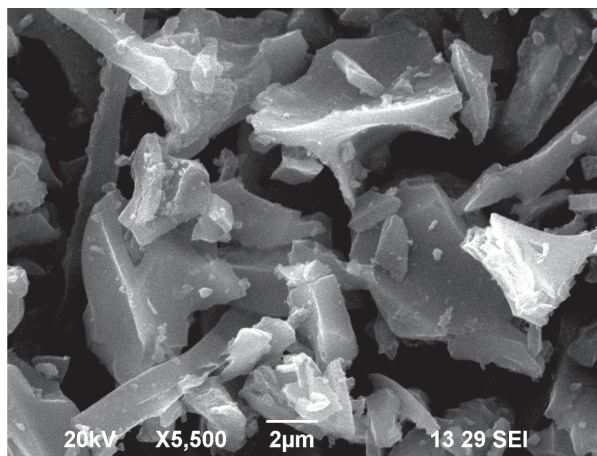


Fig. 7(b) After Adsorption

Radushkevich isotherm models are used to interpret adsorption equilibrium data. The Freundlich isotherm equation produced a very good fit for the equilibrium data. Based on pseudo-first-order, pseudo-second-order, and intra-particle diffusion equations, the kinetic research of MG on to ALSNC was carried out. The information shows that the pseudo-second-order rate is followed by the adsorption kinetics. The ALSNC could be used as an effective, affordable, accessible, and low-cost adsorbent for the elimination of MG from aquatic ecosystems, according to the study's findings.

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