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Removal of Malachite Green Dye by Teak Wood Waste Biomass Activated Carbon and Its Antimicrobial Activity

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Authors' contributions

This work was carried out in collaboration between both authors. Author SS managed the literature searches and the analyses of the study. Author GV performed the study, statistical analysis and wrote the draft of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Adsorption of Malachite Green (MG) on activated carbon obtained from *Teak wood biomass* has been investigated by batch adsorption method. The percentage removal of dye has been optimized by studying the initial concentration of the dye, adsorbent dosage, adsorption time and pH. The experimental data were found to be well fitted to Langmuir isotherm. The present study indicates that activated carbon obtained from *Teak wood biomass* is an effective adsorbent of MG dye. The prepared activated carbon was evaluated for antimicrobial activity against (*Staphylococcus aureus, Escherichia coli* and *Aspergillus flavus, Aspergillus niger*), using disc diffusion method and compared with standard antibacterial (Nitrofurantoin) and antifungal (Amphotericin B). Bacteria showing more activity than fungal strains.

Keywords: Activated carbon; adsorption isotherms; malachite green; teak wood biomass; antimicrobial.

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1. INTRODUCTION

The non-biodegradable nature of dyes pollute the environment, creating various diseases to human and animals [1,2]. Malachite green (MG) dye is highly toxic in nature, haramful to freshwater animals and humans, causing diseases. It is highly toxic to mammalian cells and organs like liver, kidney, lung, spleen, and skin [3-5]. Therefore, it is important to eliminate MG dye. The use of activated carbon for removal of malachite green has also been reported [6]. Commercial activated carbons are expensive and therefore, need to search for effective adsorbents for economical wastewater treatment. Utilizing wastes and bio-wastes of environment as adsorbents for the removal of dyes from wastewater is of interest. Number of materials such as coconut coir, bagasse pith, rice husk, neem tree leaves, and orange peel have been used to prepare carbon from agricultural wastes as low-cost adsorbent for the removal of dyes from effluents [7-11]. In the present studies, *Teak wood biomass*, a non-conventional waste material, has been used to prepare activated carbon for the removal of MG from its aqueous solutions and checking for its antimicrobial activity against some human pathogens.

2. MATERIALS AND METHODS

2.1 Adsorbate

The dye, malachite green oxalate, was supplied by BDH (India).

2.2 Adsorbents

The *Teak wood biomass* waste biomass material was obtained from Thanjavur District, Tamil Nadu, the collected plant material was washed and air dried for 15-20 days, grounded and mixed with equal amount of Conc. H_2SO_4 and stirred for 30 min. The acid- plant material slurry was heated up to 120°C for 90 min. After cooling, wet carbon material was dried at 110°C and sieved into discrete particle size and stored. The adsorbent was designated as TSAC. A stock solution of dye with known concentration (1000 ppm) was prepared.

2.3 Characterization of Adsorbent

The surface morphology of the adsorbent were visualised via Scanning Electron Microscopy (SEM). The diameter of the composite range was 10 µm.

2.4 Malachite Green Dye Solution

A stock solution of dye 1000 mg/L was prepared.

2.5 Batch Experiments

Batch experiments were conducted by the method described in Vijayalakshmi et al. [12]. Briefly, 100 ml of MG solution mixed with known amount of adsorbent, equilibrated.

2.6 Effect of Initial Aqueous pH on Adsorption

100 ml of MG dye solutions (20 mg/l) and equilibrating with 0.200 g TSAC after adjusting the solution pH varying from 5.0 to 9.0 range for 2 hours at room temperature. After equilibration time, the solutions were separated and the supernatant was analyzed for residual concentration.

2.7 Effect of Carbon Dosage

Carbon dosage effect was conducted by the method described in Vijayalakshmi et al. [12]. Briefly, The various amounts of concentration of adsorbent (0.2, 0.4, 0.6, 0.8 & 1 gm) was taken in a flask, 20 ppm MG dye as added to it. The flask was put in a shaker at 115 rpm and 35°C. The amount of dye adsorbed at time t, q_t and at equilibrium q_e was calculated by the following equation:

$$q_t = \frac{(C_0 - C_t)\, V}{m}$$

Where, q_t is the amount of dye adsorbed (mg/g) at time t, C_0 is the initial dye ion concentration (mg/L), C_t is the dye adsorbent (mg/L) at time t, V is the volume of solution (ml) and m is the mass of the adsorbent (g). When t is equal to equilibrium contact time, $C_t = C_e$, $q_t = q_e$, then the amount of dye ion adsorbed at equilibrium, q_e [12].

2.8 Adsorption Isotherms

The linear logarithmic form of Freundlich isotherm is given by,

$$\log q_e = \log k + 1/n \log C_e$$

Where q_e = x/m is the amount of dye adsorbed, Ce the equilibrium concentration, k and n are the

constants. When log q_e was plotted against log C_e a straight line was obtained with slope log*k* and y – intercept.

The linear form of Langmuir isotherm is given by,

$$\frac{C_e}{q_e} = \frac{1}{q_0 b} + \frac{C_e}{q_e}$$

where q_o is the equilibrium constant, b is monolayer capacity, C_e is the equilibrium concentration and q_e = x/m is the amount adsorbed per unit mass of the adsorbent [13].

2.9 Antimicrobial Activity

Bacterila strains *Escherichia coli, Klebsiella pneumonia, Staphylococcus aureus, Bacillus subtilis* and *Klebsiella pneumonia* and fungal strains *Aspergillus niger and Aspergillus flavus* were used.

2.9.1 Assay of antibacterial activity

Antibacterial activity was determined by disc diffusion method as described by Bauer et al. [14]. The zone of inhibition (mm) was examined after 12-18 hrs.

2.9.2 Assay of antifungal activity

Antifungal activity test was carried out following the modification of the method originally described by Bauer et al. [14]. The plates were incubated at 28°C for 72 hrs. After incubation period, the diameter of the zone were measured and expressed in mm.

2.10 Statistical Analysis

Error in data: ± 1– 2% for percentage removal ± 0.005–0.01 mg/g for amount adsorbed.

3. RESULTS

3.1 FTIR Analysis of Activated Carbon

FTIR spectrum is given in Fig. 1. 3366 cm^{-1}: stretching vibration of O–H band; 2925 cm^{-1}: stretching vibration of C-H; 1706 cm^{-1}: acidic carbonyl C=O stretching; 1036–1364 cm^{-1}: C-O stretching in phenols, alcohols, acids, ethers and esters. These groups participate in MG adsorption to TSAC.

3.2 Scanning Electron Microscope Analysis of Activated Carbon

The SEM micrograph of TSAC before and after adsorption of MG is shown in Fig. 2. Porous active centres of TSAC clearly visualized in Fig. 2.

3.3 Effect of Initial Aqueous pH on Adsorption

The increase of pH of the solution increases with adsorption of dyes from solution (Fig. 3). The adsorption capacity is found to be higher at pH 9. At acidic pH, the adsorption of the dye is low

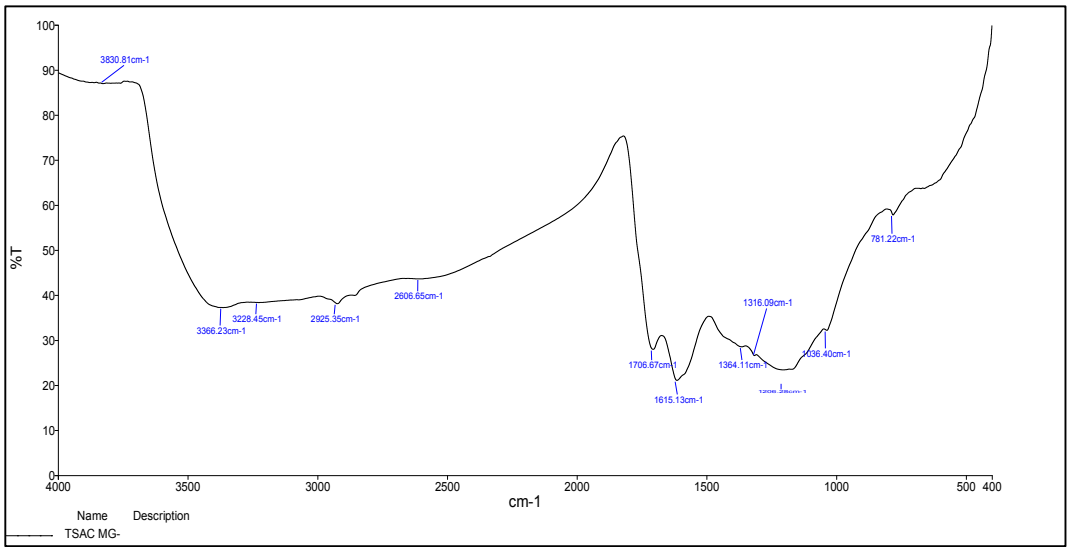

Fig. 1. IR spectrum of TSAC after the adsorption of MG dye

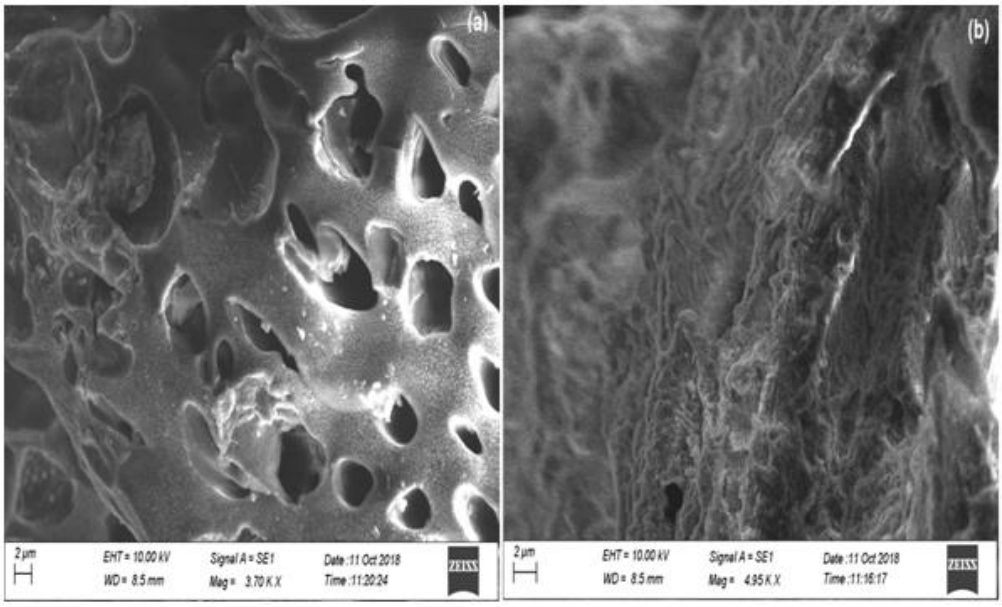

Fig.2. SEM micrographs of (a) pure TSAC (b) MG adsorbed by TSAC

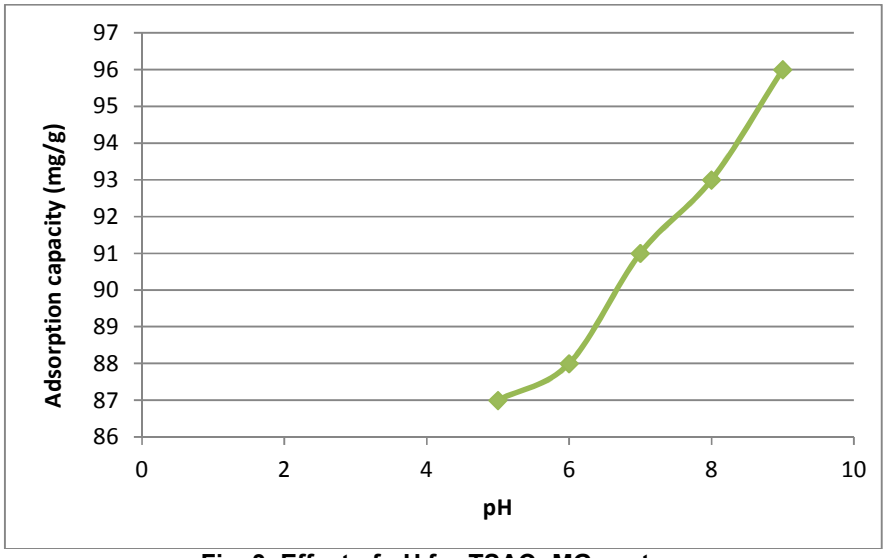

Fig. 3. Effect of pH for TSAC -MG system

Table 1. Antimicrobial activity of activated carbon

S.No.	Microorgaism Name	Zone of inhibition (mm in diameter)		
		Control	Standard*	Sample
1	*Staphylococcus aureus*	-	21	22
2	*Escherichia coli*	-	14	25
3	*Aspergillus niger*	-	22	15
4	*Aspergillus flavus*	-	24	18

**NIT-Nitrofurantoin (300 µg).AP-Amphotericin-B*

this is mainly due to the competition between the H^+ions and the cationic form of dye molecules and then the adsorption capacity of TSAC is found to be pH 9.

3.4 Effect of Carbon Dosage

From the Fig. 4, % removal of MG dye increases with increasing the TSAC adsorbent dosage. Beyond 1.0 gm of TSAC adsorbent, there was no drastic increase in the adsorption rate hence, 1.0 gm was taken as optimum dosage for removal of MG.

3.5 Adsorption Isotherms

From the Fig. 5, Freundlich isotherm is less fitted to the present adsorption study due to the less correlation coefficient value of 0.944. From the Fig. 6, correlation coefficient (R^2) of 0.999 indicating that the present study of data follow Langmuir isotherm (Fig. 6).

The antibacterial effect of activated carbon was tested against human pathogens including *Escherichia coli, Staphylococcus aureus.* The antifungal effect of activated carbon was tested against *Aspergillus niger and Aspergillus flavus.* Activated carbon showed maximum activity against *Escherichia coli* with the inhibition of 25 mm followed by *Staphylococcus aureus* with 22 mm. The zone of inhibition was found to be 18 mm for Aspergillus *flavus* and 15 mm *Aspergillus niger* (Table 1 and Fig. 7)

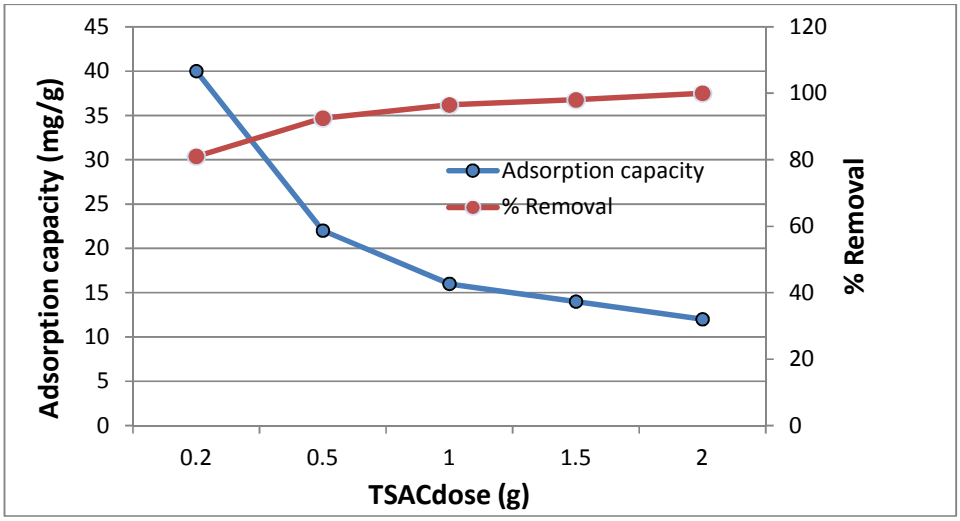

Fig. 4. Effect of carbon dosage

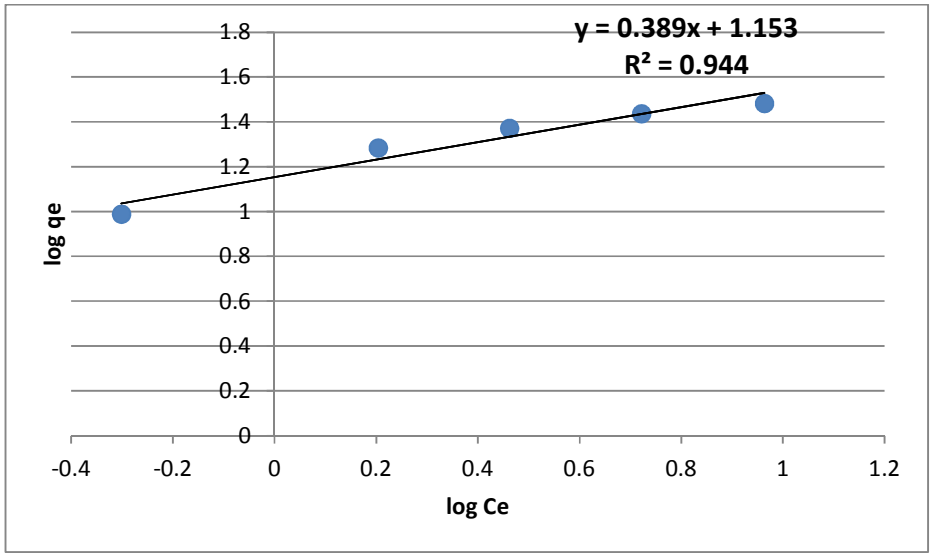

Fig. 5. Freundlich adsorption isotherm

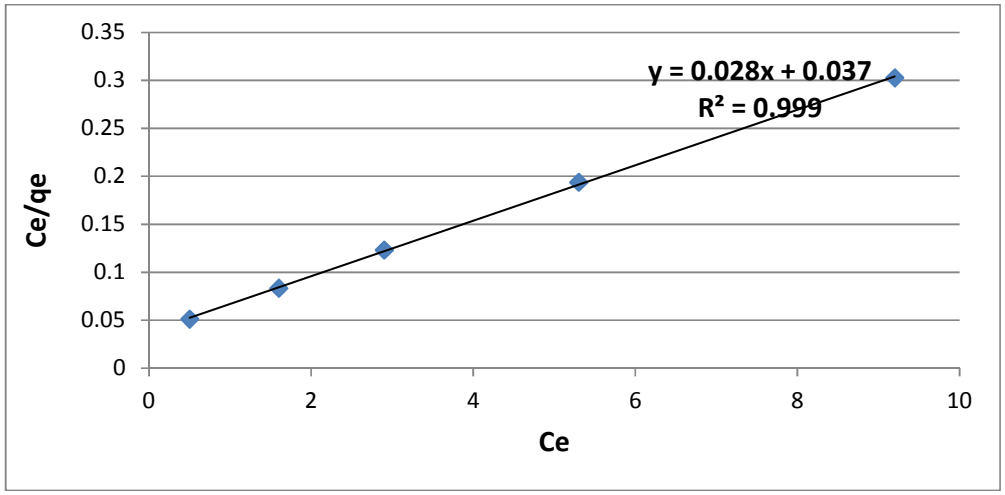

Fig. 6. Langmuir adsorption isotherm

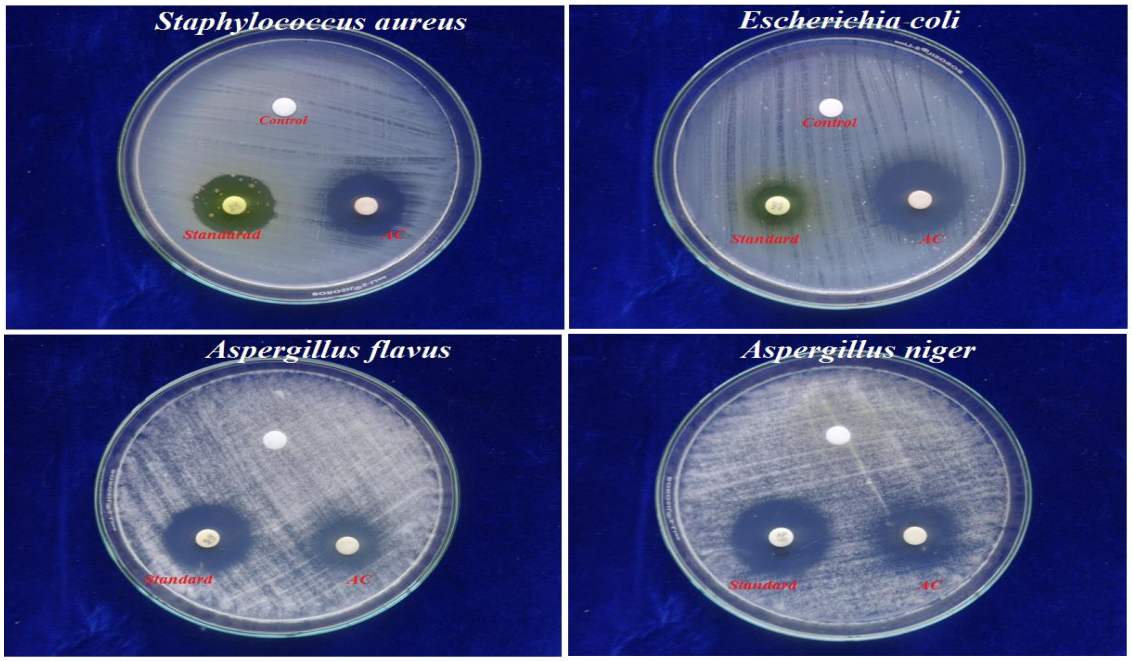

Fig. 7. Antimicrobial activity of *activated carbon* againt various human pathogens (a) *Staphylococcus aureus* (b) *Escherichia coli* (c) *Aspergillus niger* and (d) *Aspergillus niger*

4. DISCUSSION

High concentrations of MG are toxic if discharged into the aqueous environment, with carcinogenic effects on human beings and causing suffocation of aquatic plants [15]. In the present study, *Teak wood* carbon was selected as a local, cheaper and readily available adsorbent for the removal of MG dye from the aqueous solution. Among the Freundlich and langmuir model studied, the correlation coefficient (R^2) value which is very close to 1(0.999) indicating that the adsorption follows the Langmuir isotherm . This study confirmed that the TSAC has comparatively high adsorption capacity and can be used as cost effectiveness natural absorbent. Activated carbon removes or adsorb large amount of bacteria like *Pseudomonas aeruginosa* and *Escherichia coli* from fresh and potable water systems [16]. The activated carbon prepared from Teak wood bio mass showed

good antibacterial properties. Similar studies were carried out for antimicrobial activity on activated carbon and reported, which made an attempt to carry out the antimicrobial activity of activated carbon [17,18].

5. CONCLUSION

The present study indicates that activated carbon obtained from *Teak wood* waste biomass is an effective adsorbent of MG dye. For adsorption isotherm, Langmuir Isotherm is more accurate because regression coefficient was R^2 = 0.999 as comparison to R^2 = 0.944 for Freundlich Isotherm. Further the results showed that activated carbon TSAC possess maximum antibacterial activity against the tested bacterial species.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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