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# Tea Waste-Activated Carbon Utilized for Methylene Blue dye and iodine value Adsorption

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**Abstract -** *The studyinvestigates the possibility of utilizingwaste tea to generate biochar and activatedcarbon to remove methylenebluenumber (MBN) and iodine value (IV) from wastewater. As a by-product of tea production, tea waste was transformed into activated carbon, and then the effectiveness of the activated carbon in removing dye was examined through batch studies. As a result of its porousstructure and large surfacearea, the results indicated that teawaste-activated carbon has a high adsorption capacity for methylene blue. It was found that the contact time affected the adsorption process. Without oxygen, tea waste samples were treated at a range of temperatures (400, 500, 600, and activated carbon), and the resulting changes in adsorption characteristics were investigated later. Consequently, dye removal systems that take advantage of adsorption are designed to be cost-effective. During the experiment, biochar and activated charcoal were utilized for the purpose of adsorbing methyleneblue dye and determining the iodine value. The effluent and wastewater significantly reduced methylene blue dye and iodine value. Within the scope of our experimental inquiry, it was demonstrated that activated charcoal could remove significantly higher amounts of methylene blue dye and iodine value. There is a correlation between the duration of the response (60, 120, and 180 minutes) and the amount of methylene blue that is absorbed. After 180 minutes, a tea waste-activated sample was found to have achieved the highest possible percentage of methylene blue dye removal, which was 98.22%. The measurement of iodine reveals that the highest amount of adsorption that may be achieved using ACTW is 1275.68 mg/g.*

***Key Words***: Tea waste, Activated carbon, Methylene blue, Iodine value, Wastewater treatment, Adsorption capacity, Sustainable adsorbent

## 1.INTRODUCTION

In recent decades, the increasing industrialization and globalization of manufacturing processes have led to a substantial rise in the production and utilization of synthetic dyes and pigments across various industries worldwide. While these dyes contribute significantly to product aesthetics and functionality, their improper disposal and release into natural water bodies have become a growing environmental concern. Many synthetic dyes are persistent organic pollutants, resistant to conventional wastewater treatment methods. They can cause adverse impacts on aquatic ecosystems and humanhealth due to their toxic and carcinogenic properties (Aboua K. N. et al., 2015), (Abuelnoor N. et al.,2021).

Exploring sustainable and alternative sources of activated carbon, like agricultural waste products, for environmental remediation has gained attention in recent years. Tea waste, a by-product of tea production, is abundant and rich in organic constituents, making it a potential candidate for producing activated carbon with favorable adsorption properties (Shrestha, L. K. et al., (2019). Various industries, such as paper,food,plastics, and textiles, extensively use dyes, resulting in wastewater with distinctive characteristics. Organic substances in sewage, when discharged into natural water bodies, can be harmful to aquatic life, necessitating additional chemicalandbiological oxygen. Certain dyes can produce intense hues even at minimal concentrations. Techniques such as ozonation,oxidation, filtering, and coagulation with metalcompounds eliminate color from wastewater. However, these technologies often lead to high sludge production, harming the environment. Therefore, activated carbon adsorption is recognized as a promising technique for effectively removing color from wastewater with minimal waste generation (Gowtham, B. 2021), (Hussain, S., et al., 2018).

The activated carbon, generated through hydrothermal carbonization and KOH activation, demonstrated a substantial surface area of 862.2 $m^2/g$ and efficiently eliminated methylene blue of 415.8 mg/g (Tran, T. H., et al., 2020). The specific surface area of the synthesized adsorbents varied from 89 to 345 $m^2/g$, and the adsorption capabilities of the charcoal adsorbents for methyl red in an aqueous solution ranged from 26 to 135 mg/g (Paluch D. et al., 2023). Mesoporous PALB, with 816 m/g surface area and 1 nm radius, efficiently removes >98% MB dye from aqueous solution at 303 K, pH 8, 50 mg/L initial dye concentration, 0.2 g/L adsorption dose, and 30 min contact time. PALB has a high monolayer adsorption capacity (Qòmax) of 263.95 mg/g, outperforming other adsorbents for MB dye removal in aqueous solutions (Jabar, J. M. et al., 2022). The highestremoval of 246.5mg/g was attained at an initial RBBR concentration, achieving a rate of 95.33% (Gembo, R. O. et al., 2024). Mesoporous magnetic biochar (MBC) with a surface area of 94.2 $m^2/g$, achieving a maximum adsorption capacity of 353.4 mg/g (Mortada, W. I., et al., (2024).

Granular activated carbon generated from sugarcane bagasse (SCBAC) was synthesized using steam activation, resulting in a 489 $m^2/g$ surface area, and exhibited adsorption capacities ranging from 290 to 403 mg/g, with efficiencies over 90% following seven regeneration cycles utilizing ethanol (Sutthasupa, S. et al., (2023). Co-pyrolysis generated biochar, exhibiting adsorption capacities of 30.98 (20°C), 29.74 (30°C), and 31.45 (40°C) mg/g, respectively (Mei, M., et al., 2022). Activatedcarbon sourced from durian shell debris, with a surfacearea of 348 $m^2/g$ and an iodine adsorption value of 634 mg/g, and the most excellent adsorption capacity was 57.47 mg/g (Tran, Q. T. et al., 2022). Activated carbon (WT-AC) produced from waste tea, with an iodine value of 593.41 mg/g, eliminates 89.2% of MB and completely removes $Cd^{2+}$ (Mariah, M. A. A., Rovina, et al., 2023). Peanut hulls exhibited the highest adsorption effectiveness (>95%) among natural adsorbents, although activated carbon derived from sunflower shells demonstrated superior performance (Sawalha, H. et al., 2022). Biochar obtained from orange (Citrus sinensis) peels (OPBC) activated with the adsorption, exhibiting a maximumcapacity of 208.3mg/g (Jawad, A. L. I., et al., 2019). Activated carbon was synthesized utilizing $ZnCl_2$, $H_3PO_4$, $H_2SO_4$, NaOH, and KOH, with the $ZnCl_2$-derived activated carbon exhibiting the highest iodine number (1519 mg/g) and specific surface area (1029 $m^2/g$), efficiently eliminated heavy metals (99.9% Hg, 74.7%Cu (Bai, X. et al., 2023). The Langmuir isotherm accurately characterized the adsorption process, with mason pine-derived hydrochar (MPHC) demonstrating the maximum methylene blue removal capacity (155.1 mg/g) (Zhang, X., et al., 2024). Green algae Ulva lactuca (GABS) biochar, the Langmuir isotherm model most accurately characterizes adsorption, exhibiting a maximum capacity of 303.78 mg/g (Shoaib, A. G., et al., 2024). Eucheuma cottonii seaweedbiochar, resulting surface area of640 $m^2/g$, yielding a maximum adsorption capacity of 133.33 mg/g (Saeed, A. A. H., et al., 2020). Luffa vine (LVAC) porous biochar, demonstrated a substantial specific surface area (1075.17 $m^2/g$) and elevated MB adsorption capacity (559.11 mg/g). LVAC exhibited 83% efficiency following eight cycles, indicating superior recyclability (Xu, R., et al., 2024). Mugwort (Artemisia vulgaris) biochar and activated biocarbon demonstrated a substantial surfacearea (974.4$m^2/g$) and maximal adsorption capacities methyleneblue (164.14 mg/g) and iodine (948 mg/g) (Wiśniewska, M. et al., 2022). Activated carbon from pistachio with a maximum surface area attained of 1468 $m^2/g$, with methylene blue (341mg/g) and iodine (1276mg/g) adsorption capabilities, respectively (Baytar, O. et al., 2018).

This study seeks to examine the viability of employing activated carbon obtained from tea waste for the adsorption of methylene blue dye from aqueous solutions. The explicit aims are to transform tea waste biomass into biochar and activated carbon for the removal of methylene blue dye and the assessment of iodine value. This project aims to utilize tea waste as a precursor for activated carbon manufacture and evaluate its effectiveness in dye removal, thereby contributing to sustainable and eco-friendly wastewater treatment solutions and environmental protection.

## 2 Material and Methods

### 2.1 Feedstock

The tea waste was collected from the tea-making stall in Ujjain. Then, tea waste was washed many times till all the impurities were removed and sun-dried, and then hot air-oven dry for 22 hours to completely dry. Tea waste biomass was thermally processed by placing it in a zip lock beg for further use.

### 2.2 Semi-batch Pyrolysis Setup

The stainless-steel sample container contained nitrogen gas and pyrolysis product inlets and outlets. A hole for the thermocouple was on the sample container's side. Pyrolysis of tea waste for biochar. It's semi-batch. In each trial, Tea waste weighed 50 grams. In each experiment, the reactor was purged with nitrogen(N2) gas at 100 mL/min for 30 minutes to ensure an inert environment; then, nitrogen flow was adjusted to the goal flow rate. The reactor's internal pressure was 0.1 MPa throughout the experiment. In each experiment, the reactor was heated at 20°C/min from ambient temperature (30 °C) to the target temperature of 400, 500, and 600°C. After that, the reactor was kept at the target temperature (the residence time). If this occurs, the system should be allowed to cool before removing the biochar sample from the reactor. The biochar samples are designated as TW400, TW500, and TW600.

### 2.3 Chemicals used

Methylene blue dye, 0.1N Iodine solution (12.700 g of iodine and 19.100 g of potassium iodide (KI) in 1 Liter of Distilled Water),0.05N Sodium Thiosulphate solution (12.5 gm Na2S2O3.5H2O in 1 Liter Distilled water), 1% Starch solution, Activated carbon.

### 2.4 Preparation of Activated Carbon -

TW600 has been taken for further activation treatment. The TW600 was blended with KOH in a 1:1 ratio. The resulting solution was oven-dried for 18 hours. Subsequently, the dried sample was placed in a ceramic boat and within a tubular muffle furnace for two hours of heating under an argon (Ar) inert atmosphere at 800°C. Subsequently, vacuum filtration was employed to rinse the acquired sample with a 0.1M HClsolution, followed by (DI)deionized water. Subsequently, oven-dry the acquired sample for 24 hours. Subsequently, it was placed in a desiccator for the subsequent adsorption analysis. Methylene blue and iodine adsorption are utilized to evaluate the heat-treated tea waste chars and teawaste-activatedcarbon. The activatedcarbon sample derived from tea waste biochar at 600°C is designated TWAC.

## 2.5 Iodine Value or Iodine Number -

The iodine solution was standardized by adding two drops of starch solution to 10 ml of 0.1 N iodine solution in a conical flask. The iodine solution changed from a light yellow to a dark blue color. The resultant solution was titrated with 0.05N sodium-thiosulfate until it turned colorless. The burettereading corresponds to a blank reading (B). Activatedcarbon was accurately measured at 0.2 grams. It was added to the iodine flask, which needed to be dry. Then, 40 cc of 0.1N iodine solutions were added. After a proper four-minute shaking, the flask was filtered. The filtrate was collected in a dryflask, and ten cc of it wastitrated against a standard sodium-thiosulphate-solution using starch as an indicator (Jeyakumar, R. S., et al., 2014).

$$\text{Iodine Value} = C \times \text{conversion factor},$$

$$\text{Conversion factor} = (127 \times \text{Normalcy of iodine} \times 40)/(\text{Wt.of Sample blank reading})$$

$$C = (B–A)$$

## 2.6 Methylene Blue Number / Methylene Value (MNV) -

0.05 grams of activated carbon was agitated for 3 hours at 200 rpm with 100ml of MB solution to measure the methylene blue number of the carbons. The residual methylene blue concentration was then measured by measuring the absorbance at 664 nm using a UV/visiblespectrophotometer after filtering thesolution with the Whatman 41 filterpaper (Wu, Z., et al., 2014).

Calculations-

M-mass of the adsorbent in grams, V-volume of the solution in liters, and MBN-Methylene Blue Number, Co and Ce-initial and equilibrium concentrations of MB (mg/l), respectively.

## 3. Literature Survey

**Table -1:** Comparison of methylene blue adsorption using activated carbon

| S. No. | Sample Name | Iodine Value (mg/g) | Methylene Blue Number (mg/g) |
|---|---|---|---|
| 1 | Coffee husk waste | - | 415.8 |
| 2 | African almond (Terminalia catappa L) leaves | - | 263.95 |
| 3 | Mesoporous magnetic biochar | - | 353.4 |
| 4 | Sugarcane bagasse-derived activated carbon | - | 403 |
| 5 | Durian shell-activated carbon | 634 | 57.47 |
| 6 | Orange (Citrus sinensis) peels biochar | - | 208.3 |
| 7 | Green algae Ulva lactuca biochar sulfur | - | 303.78 |
| 8 | Eucheuma cottonii seaweed biochar | - | 133.33 |
| 9 | Luffa vine (LVAC) porous biochar | - | 559.11 |
| 10 | Mugwort (Artemisia vulgaris) biochar | 948 | 164.14 |
| 11 | Pistachio shells activated carbon | 1276 | 341 |

## 4. Result and Discussion

The iodine adsorption capacity per gram of carbon increased in pyrolyzed tea waste biomass, correlating with the observed changes in biomass.

**Table -2:** Iodine value at different temperatures treated biomass, and activated carbon-

| S. No. | Sample Name | Iodine Value (mg/g) |
|---|---|---|
| 1. | TWR | 390.25 |
| 2. | 400 | 591.05 |
| 3. | 500 | 649.75 |
| 4. | 600 | 705.57 |
| 5. | TWAC | 1275.68 |

According to the calibration curve, the relation between the concentration versus absorbance and the initial absorbance and final absorbance: -

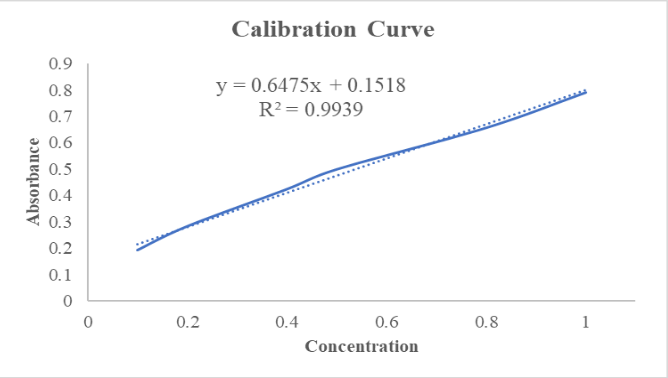

**Chart -1**: Calibration Curve for MBN

**Table -3:** Methyleneblue number for biomass, biochar and activated carbon

| S. No. | Sample Name | MBV (mg/g) 60 min. | MBV (mg/g) 120 min. | MBV (mg/g) 180 min. |
|---|---|---|---|---|
| 1. | TWR | 13.34 | 13.45 | 14.94 |
| 2. | TW400 | 32.85 | 34.85 | 40.05 |
| 3. | TW500 | 45.44 | 45.51 | 50.80 |
| 4. | TW600 | 54.08 | 54.79 | 59.49 |
| 5. | TWAC | 164.36 | 179.23 | 191.24 |

After the pyrolysis process, as the temperature rises surfacearea of the biochar also increases, and the micropores of the treated biochar boost the adsorption-capacity of iodine and methyleneblue dye following increasing order, including the following:

TWAC> 600 > 500> 400

Methylene blue adsorption increases with increasing reaction durations (60, 120, and 180 minutes). A tea waste-activated sample showed a maximum percentage elimination of 98.22% of the methylene blue dye after 180 minutes.

## 3. CONCLUSIONS

Using tea waste biochar and tea waste activated carbon (TWAC) for methylene blue dye adsorption has been extensively studied and proven to be a viable and effective method for wastewater treatment. TWAC exhibits a high adsorption capacity for methyleneblue dye due to its porousstructure and large surfacearea. This makes TWAC an efficient adsorbent for removing dyes from aqueous solutions. The contact time parameter significantly influences the adsorption efficiency. Optimizing these parameters is crucial to maximize the dye removal performance of TWAC. The adsorption of methylene blue rises as the reaction durations (60, 120, and 180 minutes) increase. A tea waste-activated sample demonstrated a maximal removal rate of 98.22% of methylene blue dye after 180 minutes. The iodine evaluation indicates that the highestadsorption capacity of ACTW is 1275.68 mg/g.

Utilizing TWAC for dye adsorption offers ecological benefits by repurposing tea waste, reducing waste generation, and minimizing synthetic adsorbents. It also provides economic advantages by utilizing a low-cost and renewable biomass resource. TWAC has diverse application potential in textiles, paper, leather, and dye manufacturing industries, where dye-contaminated wastewater is a concern. Its effectiveness and affordability make it a practical alternative to conventional adsorbents.

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