ORIGINAL ARTICLE

Characterization and Adsorptive Capacity of Gutta Percha Leaf

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ABSTRACT

BACKGROUND:
Gutta-percha leaf, a natural material derived from the gutta tree, has gained attention for its adsorptive capacity in various applications. Gutta-percha leaf is a natural material with unique properties that make it suitable for multiple applications, including its adsorptive capacity.

OBJECTIVE:
This study explored the characterization and adsorptive capacity of the gutta-percha leaf. Characterization involves analyzing the material's physical, chemical, and structural properties to understand its composition and behavior. The adsorptive capacity revealed the ability of the gutta-percha leaf to attract and retain molecules on its surface through physical interactions.

METHODS:
This study focuses on the characterization of gutta-percha leaf using scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), Thermogravimetric analysis (TGA), and X-ray diffraction (XRD) analysis. SEM imaging and FTIR analysis were utilized to investigate the surface morphology, thermal stability and chemical composition of gutta-percha leaf at the microscale level. A parametric study was conducted to analyse the effects of temperature, contact time, concentration, pH, and adsorbent dosage on the adsorptive capacity of gutta-percha leaf.

RESULTS:
The analysis revealed valuable insights into the physical, chemical, and structural properties of gutta-percha leaf, shedding light on its composition and behaviour. The adsorptive capacity of gutta-percha leaf was also demonstrated through its ability to attract and retain molecules on its surface. The results revealed insights into the surface morphology, thermal stability, chemical composition, crystalline structure, and adsorptive capacity of gutta-percha leaf under varying experimental conditions.

CONCLUSION:
The findings highlight the potential of gutta-percha leaf as an effective adsorbent in various applications due to its unique properties and adsorptive capacity. This study enhances the understanding of gutta-percha leaf's characterization and adsorptive capacity, suggesting its potential for diverse environmental and industrial applications.

KEYWORDS:
Adsorption, Characterization, Gutta Percha Leaf, Methylene blue, and Proximate analysis

INTRODUCTION

Gutta-percha leaf is gotten from gutta tree, which is native to Southeast Asia. It has been widely used in various industries due to its unique properties, including excellent electrical insulation, chemical resistance, and thermal stability. One of the lesser-known applications of gutta-percha is its potential as an adsorbent material. Adsorption refers to the process by which molecules or ions are attracted and retained on the surface of a solid material. The adsorptive capacity of gutta-percha leaves has gained attention in recent years due to their high surface area and porous structure[1].

Characterization plays a crucial role in understanding the adsorptive capacity of gutta-percha leaves. Various techniques have been employed to analyze these leaves' physical and chemical properties. Scanning electron microscopy (SEM) provides detailed information about the surface morphology and porosity of gutta-percha leaves[2]. Fourier-transform infrared spectroscopy (FTIR) helps identify the functional groups present in the material, providing insights into its chemical composition. X-ray diffraction (XRD) analysis determines the crystallinity and phase composition of gutta-percha leaves and thermogravimetric analysis determines the thermal stability of the material [3].

The adsorptive capacity of gutta-percha leaves has been investigated for various pollutants, including heavy metals, dyes, and organic compounds. The high surface area and porous structure of gutta-percha leaves make them effective adsorbents for these contaminants. The adsorption process is influenced by factors such as pH, temperature, contact time, initial concentration, and particle size.[3,4]

Understanding the characterization and adsorptive capacity of gutta-percha leaves is essential for their potential application in wastewater treatment, environmental remediation, and other fields [3]. Characterization of Gutta percha leaf was done and its ability to adsorb methylene blue dye was assessed. This research provides comprehensive analysis of the physical and chemical properties of gutta-percha leaves and their effects of physical parameters such as pH, temperature, contact time, concentration, and dosage on their adsorption of methylene blue dye.

The study aimed to explore the physical and chemical properties of gutta-percha leaves, assessing their suitability for use in adsorption processes. This is particularly relevant given the increasing need for sustainable materials in environmental applications.

METHODS

The sample of Gutta Percha tree leaves was collected from the Gutta Percha tree located on the premises of Kaduna State University School at U/Rimi, Kaduna North, Kaduna State, Nigeria. All the analysis were carried out at Umaru Musa Yaráduwa University, (UMYU) Central Laboratory, Katsina, Katsina State.

To ensure the removal of impurities, the collected leaves were thoroughly washed with distilled water. Subsequently, the leaves were air-dried. The dried leaves were then crushed and sieved with a 300 µm sieve to obtain particles of small size.

Proximate Analysis
Moisture Content
A Crucible was taken and weighed. 2 g of biosorbent sample was added to the crucible and weighed. It was kept in a hot air oven at 105 degrees Celsius for 24 hours. It was taken out and kept in a desiccator [4].

Ash content
2 g of biosorbent sample was taken in a crucible and weighed. The sample was kept in a muffle furnace for 2 hours at a temperature of $550\,^{\circ}C$, then it was taken out and kept in desiccators for half an hour (30 min) to cool down. It was again weight and ash content were calculated.[4]

Volatile matter
A crucible was taken and 2g of the biosorbent sample was weighed it was kept in the muffle furnace at a temperature of 650 degrees for 10 minutes then it was taken out and kept in the dedicator for half an hour (30 min) to cool down. The weight of the sample in the crucible was measured again percent volatile matter was calculated [4].

Carbon content
The sample was ground into smaller pieces to ensure uniformity and facilitate analysis. The sample was combusted in a furnace at high temperatures (around 1000-1200 °C)[4,5].

Characterization
The characterization of the sample was conducted utilizing a variety of analytical techniques, including Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), Thermogravimetric Analysis (TGA), and X-ray Diffraction (XRD). Each of these methods provided valuable insights into the sample's structural, compositional, and thermal properties[6,7,8].

The effect of changes in physical parameters
Test for the effect of pH
The effect of pH on the amount Of Methylene Blue removal was analyzed between the pH range of 1-14, and 15 mL of 50 mgL^{-1} methylene blue solution was transferred into a stoppered conical flask containing 0.1g of Gutta-percha tree. The mixture was agitated (150 rpm) at room temperature for 24 hours. The samples were centrifuged, and the supernatant solution was filtered. The sample was analyzed using the UV-Vis spectrophotometer. Adjustment of pH was done with HCl and NaOH[7,8].

Test for the effect of contact Time
Optimization of contact time between the solution and Gutta Percha Tree surface was
performed by contacting 0.1 g of the adsorbent with 15 mL of 50 mgL^{-1} a methylene blue stock solution for 10 to 15 min[7,8]. The pH was maintained at 8. The samples were removed from the rotary shaker and centrifuged. The supernatant solution was analyzed using the UV-Vis spectrophotometer.

Test for the effect of dosage
15 ml of 50 mgL^{-1} Methylene Blue stock solutions were contacted ranging from 0.1 g to 0.5 g. The pH was maintained at 8 and each sample was then agitated for 40 at 150 rpm. The samples were centrifuged, and the concentrations were then analyzed for Methylene Blue using the UV-Vis spectrophotometer[7,8].

Test for effect of Temperature
Adsorption experiments were carried out at 10,20, 30, 40, and 50 °C. For each sample, 15 mL of 50 mgL^{-1} Methylene Blue stock solutions were contacted with 0.1 g of percha tree. Each sample was then agitated for 40 min at 150 rpm. The samples were then centrifuged, and the supernatant was analyzed for Methylene Blue using the UV-Vis spectrophotometer[7,8].

Test for Initial Concentration
The effect of initial concentration was studied at varying 8 and 0.1 g of biosorbent was used. Agitation was done with a rotary shaker set at 150 rpm for 40 min, followed by filtration and analysis for remaining Methylene blue with the UV-Vis spectrophotometer[8,9].

RESULTS

Table 1. Proximate Analysis

Moisture content	8%
Ash content	1.0%
Volatile matter	5.9%
Carbon content	85.1%

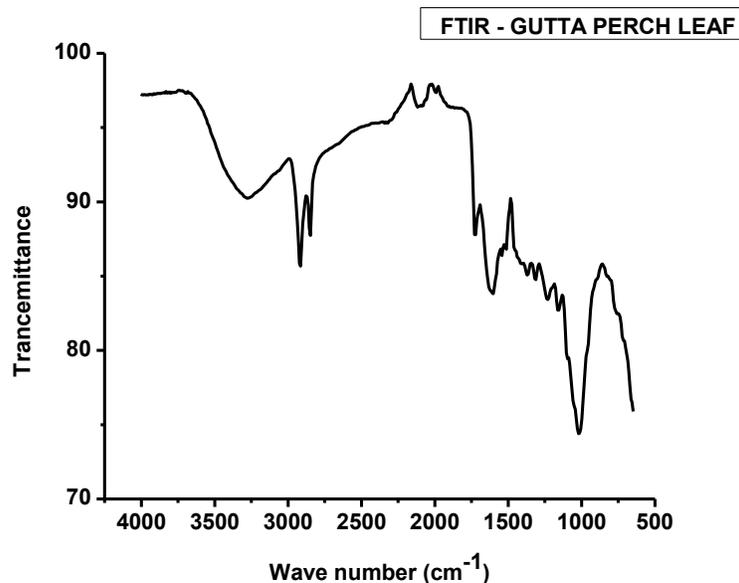**Result of FTIR analysis**

Figure 1. FTIR spectra of Gutta Percha Leaf
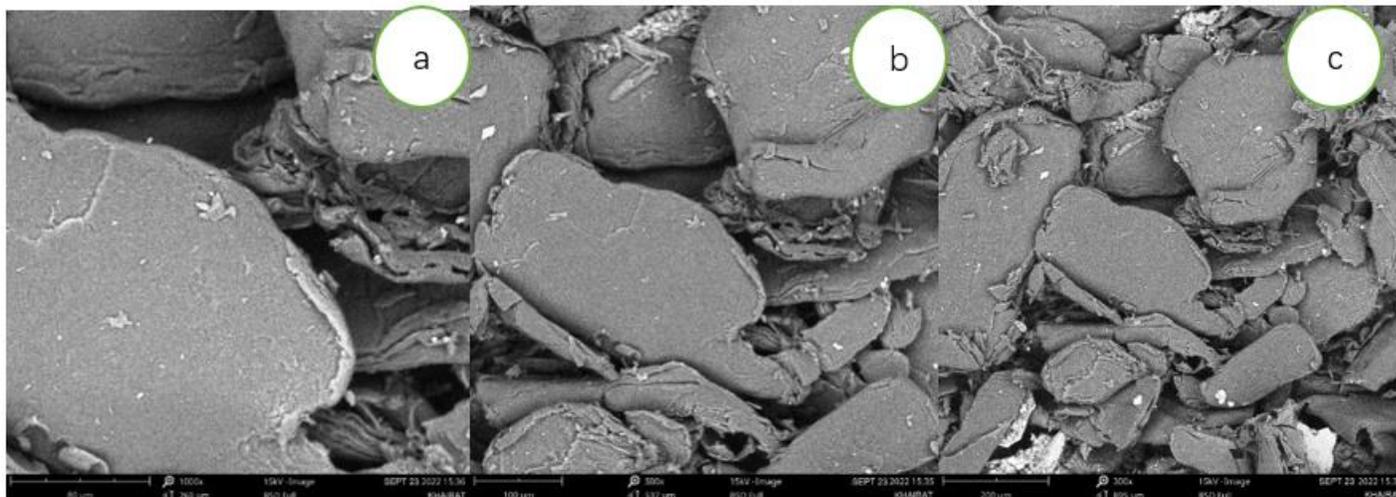
Result of SEM analysis

Figure 2. SEM image of Gutta Percha Leaf at (a) 1000X (b) 500X and (c) 300X magnification.
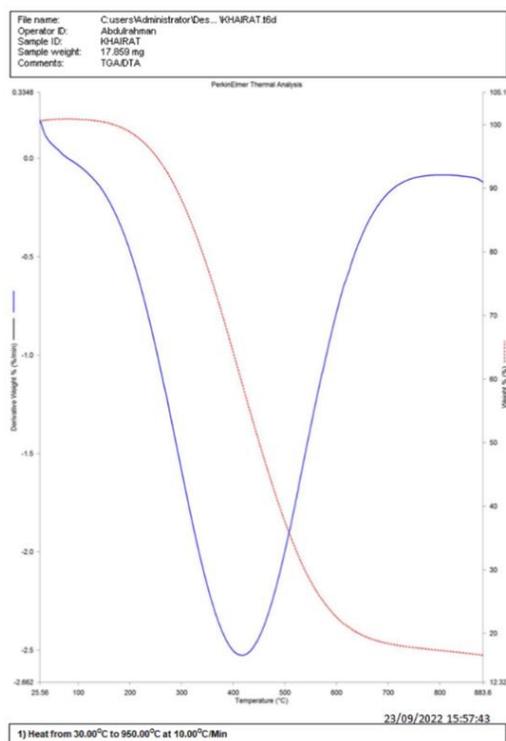
Result of TGA/DTA analysis

Figure 3. TGA pattern of Gutta Percha Leaf
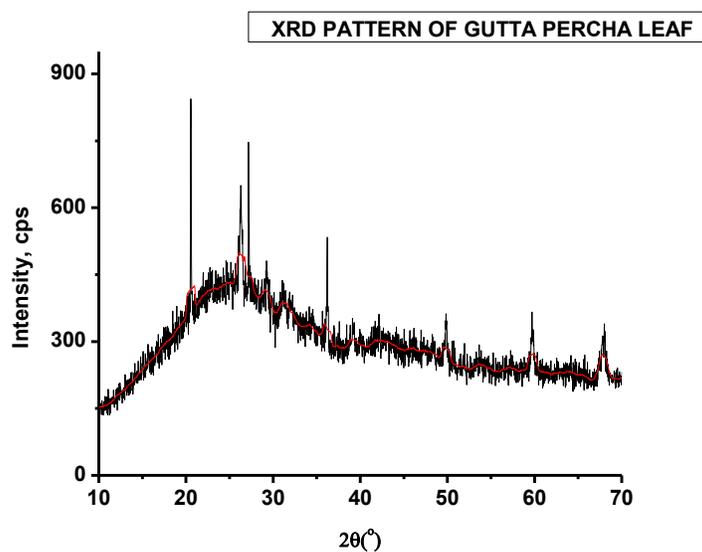
Result of XRD analysis

Figure 4. XRD pattern of Gutta Percha Leaf

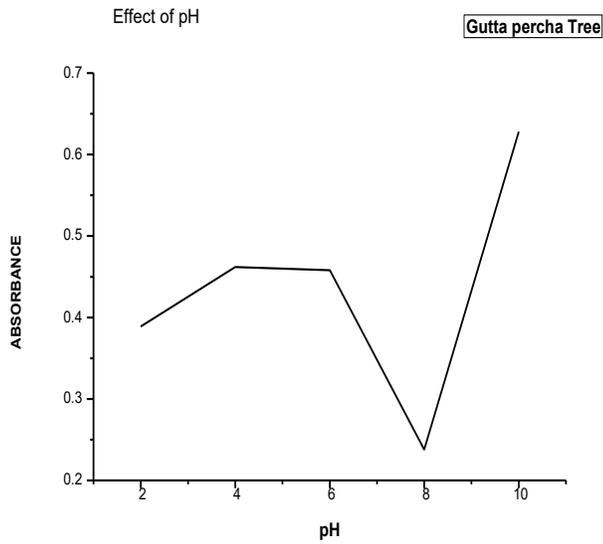## Result of the effect of experimental conditions on adsorption

Figure 5. Effect of pH methylene dye solution
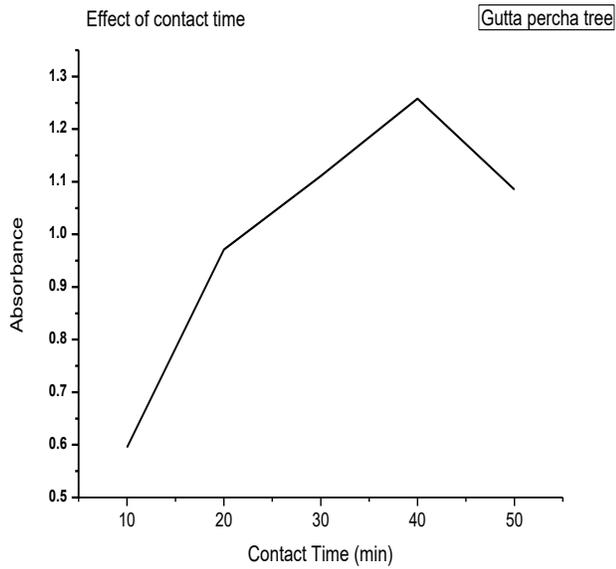

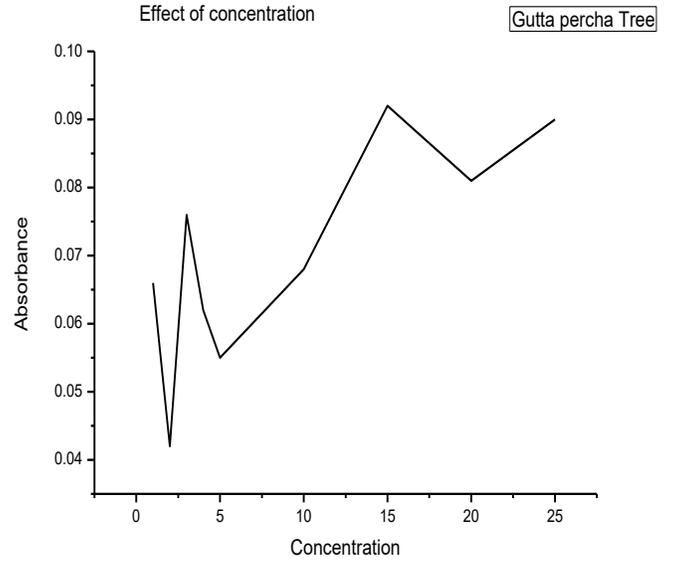**Figure 6.** Effect of concentration on biosorption of methylene blue

Figure 7. Effect of contact time on the adsorption of methylene blue
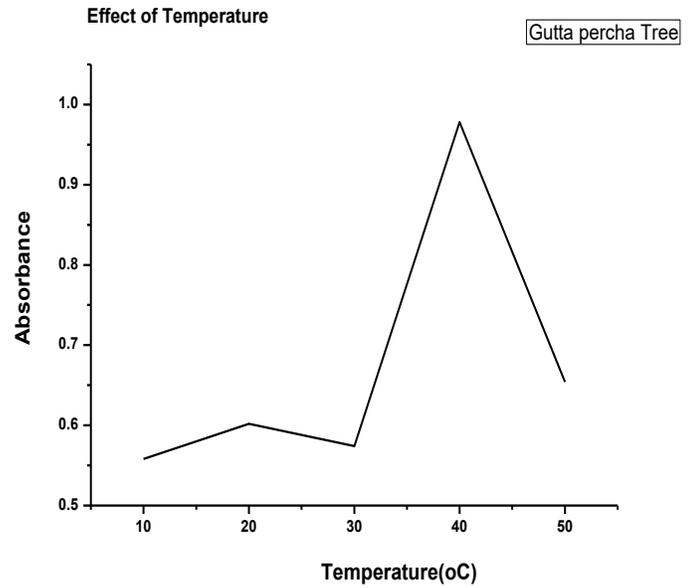

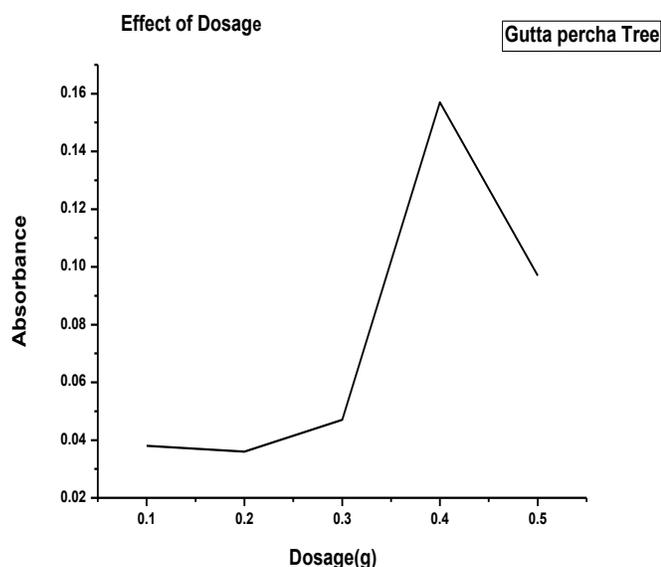**Figure 8.** Effect of temperature on biosorption of methylene blue

Figure 9. Effect of dosage on biosorption of methylene blue

DISCUSSION

Summary of key findings

The study on "Characterization and Adsorptive Capacity of Gutta Percha Leaf" presents a comprehensive analysis of the physicochemical properties and potential applications of Gutta Percha leaves as an adsorbent material. The study reveals that the leaves possess a moisture content of 8%, an ash content of 1.0%, volatile matter at 5.9%, and a high carbon content of 85.1%. These characteristics suggest a favorable composition for adsorption processes. Fourier Transform Infrared Spectroscopy (FTIR) analysis indicates the presence of various functional groups that facilitate adsorption, while X-ray Diffraction (XRD) patterns demonstrate a combination of crystalline and amorphous structures, which may enhance the material's adsorptive capabilities. Additionally, Thermogravimetric Analysis (TGA) shows that Gutta Percha leaves exhibit significant thermal stability, making them suitable for various environmental applications. Batch studies further confirm that these leaves are effective adsorbents, highlighting their potential utility in treating wastewater or capturing pollutants.

Proximate Analyses

The proximate analysis provided foundational data regarding the moisture content, ash content, volatile matter, and fixed carbon present in gutta-percha leaves. These parameters are crucial as they influence both the thermal stability and overall reactivity of the material during adsorption processes. The results indicated a relatively high volatile matter content, suggesting that gutta-percha leaves could be effective at capturing organic pollutants due to their inherent porosity and surface area[9].

Characterization

Following proximate analyses, comprehensive characterization techniques were employed to elucidate the structural properties of gutta-percha leaves. Techniques such as:

Fourier Transform Infrared Spectroscopy (FTIR) Analysis
Fourier Transform Infrared Spectroscopy (FTIR) is a technique used to analyze the chemical composition of a substance by measuring the absorption of infrared light. The resulting spectrum provides information about the functional groups present in the sample, allowing for identification and characterization (figure 1).1021.29057 cm^{-1} corresponds to the stretching vibration of C-O bonds, typically found in alcohols, ethers, or esters, 1162.9294 cm^{-1} is associated with the stretching vibration of C-N bonds, commonly found in amines or amides, 1237.47616 cm^{-} represents the stretching vibration of C-O bonds in carboxylic acids or esters, 1312.02292 cm^{-1} corresponds to the stretching vibration of C-N bonds in aromatic amines, 1371.66032 cm^{-1} is associated with the bending vibration of CH_3 groups, 1610.20995 cm^{-1} represents the stretching vibration of C=C bonds, typically found in conjugated systems or aromatic compounds, 1729.48476 cm^{-1} corresponds to the stretching vibration of C=O bonds, commonly found in carbonyl compounds such as aldehydes, ketones, or carboxylic acids, 2847.68611 cm^{-1} is associated with the stretching vibration of CH_2 groups, 2922.23286 cm^{-1}: This wavenumber represents the stretching vibration of CH_3 groups, and 3280.05730 cm^{-1}, corresponds to the stretching vibration of O-H bonds, typically found in alcohols or carboxylic acids. These wavenumbers provide information about the functional groups present in the analyzed sample,

allowing for the identification and characterization of the chemical composition which is per the literature [7,9].

Scanning Electron Microscope (SEM) Analysis
Scanning Electron Microscope (SEM) is a powerful tool used in various scientific fields to observe the surface of materials at high magnification. The SEM result provided (figure 2) indicates different magnifications at specific distances. Magnification of 1000X at 80 µm: This means that when the sample is observed under the SEM at a distance of 80 µm, it will appear 1000 times larger than its actual size. This level of magnification allows for a detailed examination of the sample's surface features. Magnification of 500X at 100 µm: At a slightly greater distance of 100 µm, the sample will appear 500 times larger than its actual size. This magnification level provides a balance between observing fine details and having a broader view of the sample. Magnification of 300X at 200 µm: When observing the sample from a distance of 200 µm, it will be magnified by a factor of 300. This lower magnification allows for a wider field of view, which can be useful when studying larger structures or areas on the sample's surface. Therefore, as the distance from the sample increases, the magnification decreases. This relationship allows researchers to choose an appropriate level of magnification based on their specific needs for observation and analysis as reported in the literature [7,9].

Thermogravimetric Analysis/Differential Thermal Analysis (TGA/DTA)
Thermogravimetric Analysis/Differential Thermal Analysis (TGA/DTA) is a combined analytical technique used to study the thermal behaviour of materials. It involves measuring the weight changes (TGA) and temperature changes (DTA) of a sample as it is subjected to controlled heating or cooling. The results obtained from TGA/DTA experiments (Figure 3) provide valuable information about the composition, stability, and thermal properties of the material under investigation. The weight loss observed at temperatures below 300 degrees indicates that there is a process occurring that leads to the removal of volatile components or decomposition of the sample. This weight loss can be attributed to factors such as evaporation of solvents, desorption of adsorbed species, or decomposition of unstable compounds.

The stability observed at temperatures above 700 degrees suggests that the sample has reached a state where further weight loss or significant thermal changes are unlikely to occur. This stability could indicate the presence of thermally stable compounds or the completion of any decomposition processes that may have occurred at lower temperatures. The sharp curve observed in the DTA plot at 420 degrees indicates a significant change in heat flow or energy absorption/release by the sample at this temperature. This change could be associated with phase transitions, chemical reactions, or other thermal events occurring within the material.

Based on the TGA/DTA results provided, it can be inferred that there is weight loss below 300 degrees due to volatile component removal or decomposition. The sample exhibits stability at temperatures above 700 degrees, suggesting a lack of significant thermal changes. The sharp curve in DTA at 420 degrees indicates a notable change in heat flow or energy absorption/release as reported in the literature [9,15].

X-ray diffraction (XRD) Analysis
X-ray diffraction (XRD) is a technique used to analyze the crystal structure of materials. It involves shining X-rays onto a sample and measuring the angles at which the X-rays are diffracted. These angles, known as 2θ angles, provide information about the spacing between atomic planes in the crystal lattice and the angles are 20.5536, 26.2873, 27.1855, 29.2103, 36.2149, 49.8668, 59.6937, and 67.9164, (Figure 4) this is following the report[8,14]. These techniques confirmed that gutta-percha leaves possess significant potential as an adsorbent material.

Adsorption studies
The final phase involved systematic adsorption studies where various parameters such as contact time, initial concentration of pollutants, pH levels, and temperature were varied to assess their impact on adsorption efficiency[10]. The results demonstrated that gutta-percha leaves exhibited high removal rates for selected contaminants under optimal conditions. The research on the parametric analysis of methylene blue adsorption on gutta-percha revealed that the optimal pH for this process is 6. The study identified an adsorbent dosage of 0.4, a contact time of 40 minutes,

and a methylene concentration of 15 ppm as the most effective parameters for the adsorption process[11]. These specific conditions (Figures 5-9) were determined through rigorous experimentation and analysis, highlighting the significance of optimizing various parameters to improve the efficiency of methylene blue removal using gutta-percha as an adsorbent material.

Strengths and limitations of the study

The strength of this study lies in its systematic approach to investigating the parameters affecting methylene blue adsorption on gutta-percha. The rigorous experimentation and analysis conducted provide valuable insights into optimizing the process for maximum efficiency. However, it is limited to the study focused solely on gutta-percha as an adsorbent material, potentially limiting the generalizability of the findings to other materials or scenarios.

Comparison with previous studies on the topic

The study on the "Characterization and Adsorptive Capacity of Gutta Percha Leaf" aligns with previous research that investigates the adsorptive properties of natural materials for environmental remediation. Similar to earlier studies, such as those examining agricultural waste products or other plant materials, this study emphasizes the potential of organic matter as low-cost adsorbents for wastewater treatment. For instance, while previous studies often focused on the chemical composition and surface characteristics of adsorbents, this study utilizes a comprehensive approach by incorporating FTIR, XRD, and TGA analyses to provide a multi-faceted understanding of Gutta Percha leaves' structural and thermal properties. The findings reveal that Gutta Percha leaves possess a high carbon content and significant thermal stability, which is consistent with findings from studies on other biomass materials that report similar characteristics enhancing adsorption capacity. However, unlike some previous studies that primarily focus on one type of pollutant or specific conditions, this study suggests broader applicability in treating various pollutants due to its robust characterization methods. The strengths of this study lie in its detailed analytical techniques and the holistic assessment of both physical and chemical properties, which may offer insights into optimizing

adsorbent performance compared to prior works that may have been limited in scope or methodology [12,13,14].

Interpretation of the findings

The findings suggest that optimizing parameters such as pH, adsorbent dosage, contact time, and pollutant concentration can significantly enhance the efficiency of methylene blue adsorption on gutta-percha. This study will help in designing effective water treatment processes aimed at removing pollutants like methylene blue from contaminated water sources.

Implication of the findings

The implications of this research extend to environmental remediation efforts, particularly in wastewater treatment where methylene blue contamination is a concern. By identifying optimal conditions for methylene blue adsorption on gutta-percha, this study contributes valuable information that can guide future research and practical applications in water treatment technologies.

CONCLUSION

Low-cost agricultural waste of Gutta-percha trees can be effectively used to remove methylene blue dye from water. The sorption of Methylene Blue Dye onto Gutta Percha leaf biosorbent is dependent on the initial Methylene Blue concentration. The adsorption process was found to be highly pH dependent, with pH 10 being optimal and 0.4 g for Dosage was required at saturation point. Temperature experiments revealed that the dilute. Methylene solutions reached equilibrium after 40 min. The results show that pH, dosage, initial concentration, and contact time can influence the rate of adsorption of methylene blue by Gutta percha leaves. The Gutta-percha Sample was characterized using Scanning electron microscopy (SEM), Fourier-transform infrared (FTIR) spectrophotometry, and thermogravimetric analysis (TGA) and XRD (X-ray Diffraction Instrument) was carried out on the Biosorbent Gutta percha Tree Leaf and the project work Research was demonstrated is Economical and Environmentally Friendly.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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