E-ISSN: 1115 – 8492 P-ISSN: 3027 - 0693
MPRI-JNSAR
INTERNATIONAL JOURNAL OF NATURE AND SCIENCE ADVANCE RES.
VOL. 08 NO. 9 APRIL, 2025

ADSORPTIVE REMOVAL OF METHYL ORANGE DYE USING BIOCHAR PREPARED FROM HIBISCUS FLOWER JUICE RESIDUE

YAGANA B. ABBA[1]; FATIMAH M. KNTAPO[2]; & JULIANA B. GAMBO[3]

1 & 2Dept of Applied Chemistry, College of Science and Technology, Kaduna Polytechnic.
[3]Dept of Applied Biology, College of Science and Technology, Kaduna Polytechnic

Corresponding Author:
yaganababaabba@gmail.com

DOI: https://doi.org/10.70382/mejnsar.v8i9.041

Abstract

Dyes are natural or synthetic soluble organic colourants containing chromophoric compounds within their chemical structure. They are employed in different industrial sectors such as textile, food, pharmaceutical, leather, plastics etc, About, 10-15 % of these get streamlined into water bodies as effluents leading to several environmental and health problems. Biochar is a porous, carbonaceous, black solid residue similar to charcoal obtained by the pyrolysis of biomass at a temperature range of 350-900℃ in an oxygen-deficient environment. In this study, biochar was produced by slow pyrolysis method in a muffle furnace at three different temperatures (300, 400 and 500℃) using *Hibiscus sabdariffa* flower residue for the adsorptive removal of methyl orange dye. It was characterized and applied for adsorptive

Keywords: Biochar, *Hibiscus sabdariffa flower* juice residue, adsorption, methyl orange.

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

removal of 50mg/L methyl orange with different adsorbent dosages (0.2-1g) and time (10-60minutes) The proximate parameters of the biochar were also analysed and HRB 500°C had the highest yield (93.26%) and highest carbon content (75.10%) with the least moisture content (4.87%). The SEM image and FTIR spectra of the biochar produced at 500°C were analysed for functional groups and surface properties respectively. SEM image showed a rough flaky texture with cracks and crevices suggesting a well-developed surface area of carbonaceous material. The OH and COOH groups aided adsorption through hydrogen bonding. The biochar produced at 500°C was applied for the adsorption of methyl orange while varying the adsorbent dosage (0-1g) and time (0-60mins) at a fixed initial concentration and volume. The Langmuir and Freundlich adsorption isotherms constants were determined and adsorption occurred through both monolayer and multilayer interactions.

Introduction

Dyes are soluble organic colourants containing chromophoric compounds within their chemical structure (Alegbe & Uthman 2024). They are natural or synthetic chemical substances employed in different industrial sectors such as textile, food, pharmaceutical, leather, plastics etc. About 7×10^7 tons of these synthetic dyes are used all over the world with the textile industries using more than 10,000 tons (Al-Tohamy et al., 2022). These dyes are highly soluble and about 10-15 % get streamlined into water bodies as effluents leading to several problems (Roy & Satha 2021). These dyes affect the beauty of water bodies and the rate of photosynthesis by blocking sunlight from coming into contact with plants (Leslie et al., 2019). This process decreases dissolved oxygen levels negatively imparting marine living species (Nishat et al., 2023). Its persistent presence through the water cycle leads to environmental pollution. Most synthetic dyes may be consumed through the food chain pathway and can bioaccumulate causing toxicity, carcinogenicity or mutagenicity (Leslie et al., 2019). Complex dyes are often difficult to remove using conventional wastewater

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

treatment techniques (Yaseen, 2025). However, adsorption is a widely used process in wastewater treatment, especially in industries such as textiles, leather, food, and paper, where large amounts of coloured effluents are generated. This method is preferred due to its simplicity, effectiveness and cheapness compared to other treatment methods Satyam & Patra (2024). Dye adsorption refers to the process by which dye molecules are removed from a solution (adsorbate) by adhering to the surface of a solid material, known as the adsorbent (Yaseen, 2025). Several materials that have been applied for adsorbing dyes from water are activated carbon, zeolites, clay, biosorbents, nanofibers, and biochar (Yagub et al., 2014).

Biochar is a porous, carbonaceous, black solid residue similar to charcoal obtained by the pyrolysis of biomass at a temperature range of 350-900°C in an oxygen-deficient environment that can be used as a main product or a major constituent of blended products (Khater et al., 2024). It has been applied by several researchers for various dye adsorption studies. The roselle flower extract is typically used for making juices leaving behind a significant amount of residue in the form of exhausted leaf which can be used for preparing a value-added product. The aim of this work is to produce biochar using *Hibiscus sabdariffa* flower residue for the adsorptive of methyl orange dye.

Roselle plant with botanical name, Hibiscus sabdariffa, belongs to the the *Malvaceae* family. It is an annual summer shrub cultivated annually and has a lot of nutritional benefits. It is mostly consumed as food but can be used for medicinal purposes. The leaves are mostly green or red. Hibiscus flowers are typically utilized to prepare juices, tea, and soups. They also serve as natural colouring agents in foods (Shruthi & Ramachandra, 2019). The white ones are mostly used for soups while the red ones are used for making juices and tea (Shruthi & Ramachandra (2019). It is mostly planted in Malaysia and India but is cultivated in Nigeria (Onyeukwu et al., 2023). In Nigeria they mostly planted in Katsina, Plateau, Nasarawa, Borno, Ondo and Osun (Onyeukwu et al., 2023). Hibiscus juice waste can be used for biochar production thereby offering a sustainable solution to reducing waste and producing a valuable product that could be used for the removal of contaminants

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

from water such as dyes, pesticides, herbicides, toxic metals etc, aiding pollution control (Danesh *et al.*, 2022).

Material and Methods

Chemicals and Reagents

All chemicals and reagents used were analytical grade including methyl orange. Methyl orange is an azo dye with MF $C_{14}H_{14}N_3NaO_3S$ and MM=327.33 g·mol^{-1}. It appears as an orange or red powder and is soluble in water. It forms an orange colour in acidic media and yellow in basic media.

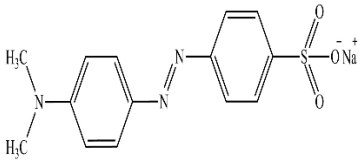


Figure 1: Chemical structure of methyl orange

Instruments

Analytical balance, muffle furnace, UV-visible spectrophotometer (UV2550, Shimadzu), FTIR spectrophotometer (8400s, Shimadzu), Scanning Electron Microscope (SEM/EDX) Analyser, magnetic stirrer.

Sample Collection and Preparation

Feedstock Preparation

Hibiscus flowers were purchased from the market, washed, and then cooked in water to extract the juice, resulting in a beverage hibiscus flower juice popularly known as "zobo drink". The residue from the hibiscus flowers was washed thoroughly and dried at room temperature for 3 days. Subsequently, the dried samples were placed in a laboratory oven at 105°C to a constant weight to remove any remaining moisture. Samples were ground and stored in an airtight container before proceeding with the pyrolysis procedure.

Biochar Preparation by Slow Pyrolysis

The pyrolysis experiments were carried out in a box-type muffle furnace under limited oxygen. The hibiscus flower residue was placed in a ceramic crucible with

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

a lid and subjected to pyrolysis at different temperatures (300, 400 and 500 °C) for 2 hours at a heating rate of 10 °C/ 1min. The samples were cooled and the percentage yield for each biochar was obtained. The samples were labelled HRB 300°C, HRB 400°C and HRB500°C, respectively. Where HRB means Hibiscus Residue Biochar.

Proximate Analysis of Biochar

The following proximate properties (Moisture Content MC (%), Ash content AC (%), Volatile Matter VM (%), Fixed carbon FC (%), Bulk density ($Kg.m^{-3}$), Surface area and pH) of the biochar were analysed in triplicates.

Ultimate Analysis of Biochar

The ultimate characterization of the biochar with the highest percentage yield (HRB 500°C) was analysed by EDX analysis.

Preparation of Methyl Orange Solution

A 100ppm of stock solution of methyl orange was prepared by dissolving an appropriate amount of MO in distilled Water and placed in a volumetric flask and made up to the 1000mL mark. A different concentration range of methyl orange was prepared from the stock solution (10-50 ppm). A calibration curve of absorbance/concentration was constructed using a UV-Vis Spectrophotometer at a max wavelength of methyl orange (464nm) using Microsoft Excel.

Batch Adsorption Study

The biochar with the least ash content and highest yield was chosen for the adsorption study and this was HRB500 °C**.** The adsorption of the MO was done by varying the adsorbent dosage and the adsorption time.

Effect of adsorbent Dosage

To determine the effect of adsorbent dosage 20 mL each of the dye solutions at initial concentration of 50 mg/L were reacted with varied HRB adsorbent doses

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

(0.2, 0.4, 0.6, 0.8, and 1.0 g) in covered conical flasks. The set-up was agitated for 60 mins at room temperature and the solutions were filtered.

Effect of Time

To determine the effect of time on the absorption, 20 mL of each dye solution at an initial concentration of 50 mg/L was reacted with 0.6 g of adsorbent at different times ranging 10 -60 minutes at 10-minute intervals. The data obtained was used to plot Langmuir and Freundlich isotherms which describe the adsorption process.

Determination of Equilibrium Concentration (Ce)

The absorbance of the sample after adsorption was determined by the UV-Vis Spectrophotometer. The equilibrium concentration was calculated using the equation for the calibration curve derived from a linear regression of the standard concentration (initial concentration of dye) versus absorbance of the sample after the adsorption process which equation takes the general form: y=mx+c as shown in Fig 2. y = 0.0206x - 0.0052x.

From the initial concentration, Co and equilibrium concentration, Ce values of the adsorbate (methyl orange), V the dye solution volume and m the adsorbent (HRB) weight. The % removal of MO dye was calculated based on the following equation;

$Removal\ (\%) = \frac{Co-Ce}{(Co)} \times 100.$

The amount of dye adsorbed per gram (Qe) was calculated based on the following equation: $Qe = \frac{(Co-Ce)\times V}{m}$.

Kinetics of Adsorption

In this work, Langmuir and Freundlich isotherm models were applied to describe the features of equilibrium adsorption.

Langmuir isotherm

This is the most popular adsorption isotherm describing monolayer adsorption with the theoretical equation expressed as $\frac{Ce}{Qe} = \frac{1}{kl} + \left(\frac{al}{kl}\right) Ce$ (Wang & Guo, 2020). A plot of Ce versus Ce/Qe will show the applicability of Langmuir adsorption

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

isotherm for methyl orange. KL and aL are the Langmuir constants related to adsorption capacity and rate of adsorption, respectively which are calculated from slope and intercept of the plot Ce versus Ce qe. The essential characteristics of Langmuir adsorption isotherm can be expressed in terms of a dimensionless constant, separation factor or equilibrium parameter ,,RL" which is defined by, $R = \frac{1}{1+aL.Co}$

Where, Co = initial concentration of the dye and al=Langmuir constant. If RL > 1 Unfavorable, RL=1 Linear, 0 < RL < 1 Favorable, RL= 0 Irreversible (Hasan & Alfotaisi, 2020).

Freundlich isotherm

The Freundlich isotherm equation model describes non-ideal sorption processes involving heterogeneous adsorption as depicted by q=KC. The linearized form of the equation in logarithm form is given as log qe = log KF + $\frac{1}{n}$ logCe (Wang & Guo, 2020). KF is the Freundlich constant related to the bonding energy and n the adsorption intensity. 1/n values indicate the type of isotherm to be irreversible (1/n = 0), favorable (0 < 1/n < 1), unfavorable (1/n > 1) (Hasan & Alfotaisi 2020).

Results and Discussion

Proximate Analysis of HRB 300°C, HRB 400°C and HRB 500°C

Table 1: Proximate Analysis of Biochar

Proximate Parameters (mean of 3 replicates)	HRB 300°C	HRB 400°C	HRB 500°C
Percentage Yield (%)	83.41	88.45	93.26
Moisture Content MC (%)	5.58	5.03	4.87
Ash Content AC (%)	4.89	5.63	6.21
Volatile Matter VM (%)	11.73	10.26	9.94
Fixed Carbon FC (%)	73.21	74.94	75.10
Bulk density (Kg.m^{-3})	198.7	195.6	195.3
pH	7.4	7.8	7.2

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

The proximate properties are displayed in Table 1. The MC content range (4.47-5.58) % did not exceed 10 % which can positively influence the adsorption capacity of biochar. Leading to porosity and more active sites during adsorption. High carbon content means low volatile matter and an increase in porosity which may aid adsorption (Weiber & Quicker, 2018). A high value of FC (73.21-75.10) % shows a carbon-rich matrix and improves the surface of biochar for interaction with adsorbates. A low ash content means higher adsorption features for adsorbates (Natrayan et al., 2022). The results of the pH measurements of hibiscus biochar at three different temperatures (300, 400, and 500°C). The are 7.4 at 300°C, 7.8 at 400°C, and 7.2 at 500°C. The results from this study were regarded as being in keeping with references in the literature that show pyrolysis-produced dry biochar has led to an increase in carbon content, surface area, and pH but reduced volatile matter (Tomczyk et al., 2020). For this study, the higher pyrolysis biochar was used due to higher yield and FC content even though certain functional groups (COO-, or -OH) needed for cation exchange may be lost. Alkaline pH is mainly caused by the formation of carbonates and inorganic alkalis (Ding et al., 2014).

Ultimate Analysis of Biochar (HRB 500°C)

Table 2: Ultimate Analysis of Biochar (HRB 500°C)

Element	Atomic Concentration	Weight Concentration
Carbon (%)	73.03	54.96
Potassium (%)	5.47	13.41
Aluminium (%)	6.90	11.67
Chlorine (%)	4.60	10.21
Nitrogen (%)	8.83	7.75
Sodium (%)	0.56	0.81
Magnesium (%)	0.31	0.47
Iron (%)	0.11	0.39
Silicon (%)	0.10	0.18
Sulphur (%)	0.08	0.15

The SEM/EDX elemental composition (Table 2) indicates that the adsorbent is primarily carbon-based (73.03%), with insignificant amounts of potassium (K), aluminium (Al), chlorine (Cl), and nitrogen (N). High carbon content suggests an

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

organic nature, making it suitable for adsorption due to porosity and surface functionalization. The oxides of elements such as potassium, sodium and magnesium impart basicity to the biochar's surface, enhancing its ability to attract MO which is acidic (Lee et al., 2024). This leads to mechanisms such as electrostatic interactions, cation exchange, and surface complexation promoting the adsorption of negatively charged pollutants as seen in a similar study (Lee et al., 2024).

SEM Analysis of Biochar (HRB 500°C)

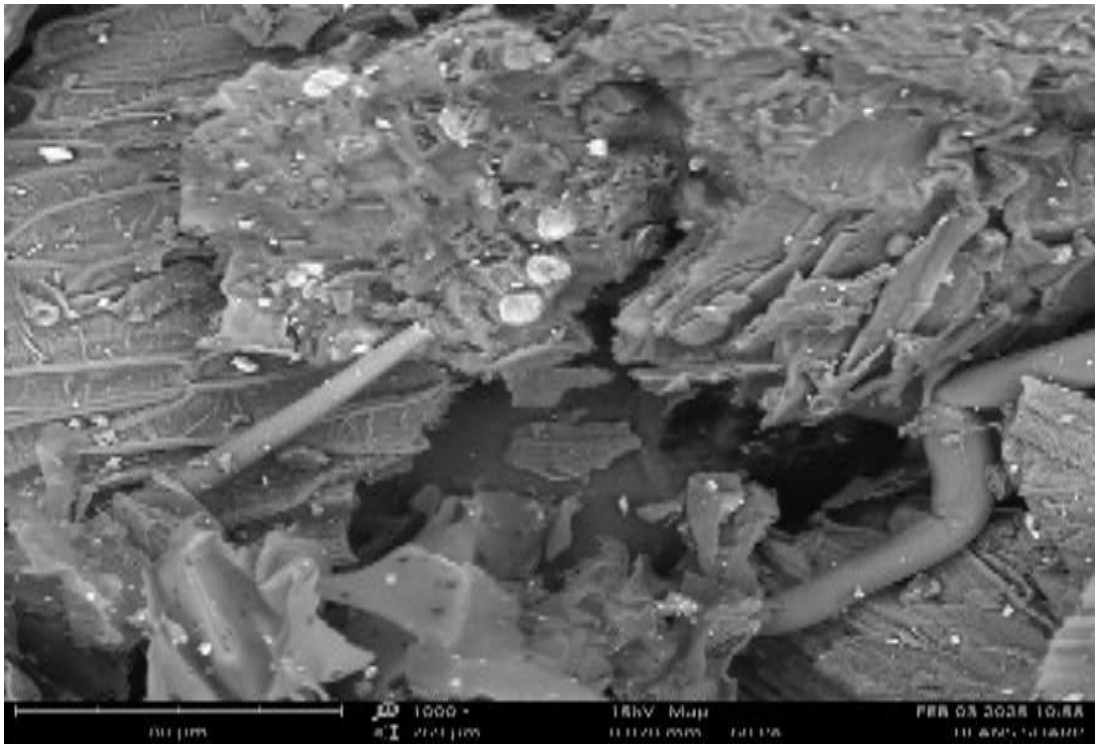


Figure 2: SEM analysis of Biochar (HRB 500°C)

Magnification of biochar was done at 1000× at a length of 80 µm showing fine surface features down to the micron size as shown by Fig 2. The SEM image for the hibiscus juice residue biochar exhibits a highly porous and irregular surface, which is characteristic of biochar and is expected to be used for adsorption applications such as dye removal similar to a work by (Saghir *et al*., 2022). The SEM image shows a rough flaky texture with cracks and crevices suggesting the

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

presence of a well-developed surface area carbonaceous material (Leng *et al*., 2021). These properties can enhance the adsorption capacity. The bright spots distributed across the surface could indicate mineral deposits or residual ash content from the biomass feedstock could contribute to the surface reactivity of the biochar (Seow *et al*., 2022). Some elongated, fiber-like filamentous features are visible, which could be remnants of biomass-derived cellulose or lignin structures that were not completely carbonized (Zubair *et al*., 2020).

FTIR Spectroscopic Analysis of HRB 500℃

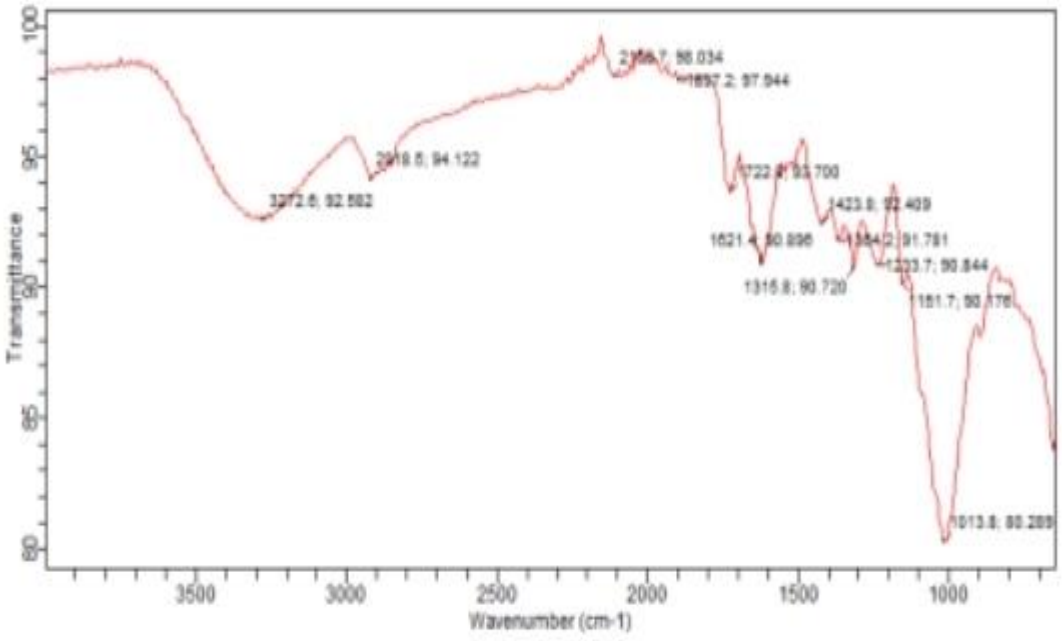


Figure 3: FTIR Spectroscopic Analysis of HRB 500℃

The Biochar has several functional groups that enhance its capacity to adsorb dyes, according to FTIR analysis as enumerated in Fig. 3. Hydroxyl groups strengthen hydrogen bonds and increase adsorption efficiency, the broad peak at 3272.6 cm^{-1} is indicative of O-H stretching and O-H bending (1423.8 cm^{-1}, 1315.8 cm^{-1}) (Cheng et al., 2021). Carbonyl groups are indicated by the C=O stretching at 1722.0 cm^{-1} and esters are suggested by the C-O stretching at 1151.7 cm^{-1} (Cheng et al., 2021). The -OH and -COOH groups can form hydrogen bonds with the azo (-

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

N=N) group and sulfonate ($-SO_3^-$) group of methyl orange which ultimately aids adsorption The S=O stretching at 1013.8 cm^{-1} suggests sulfonated compounds that improve water solubility and dye binding efficiency, the presence of C-N stretching (1233.7 cm^{-1}) indicative of amines can facilitate adsorption through ionic interactions with anionic dyes. The adsorption process from the FTIR spectral analysis might indicate that adsorption was through physisorption processes such as hydrogen bonding and dipole-dipole attractions between sulfonate ($-SO_3^-$) group on the methyl orange and the -OH and -COOH groups on the biochar.

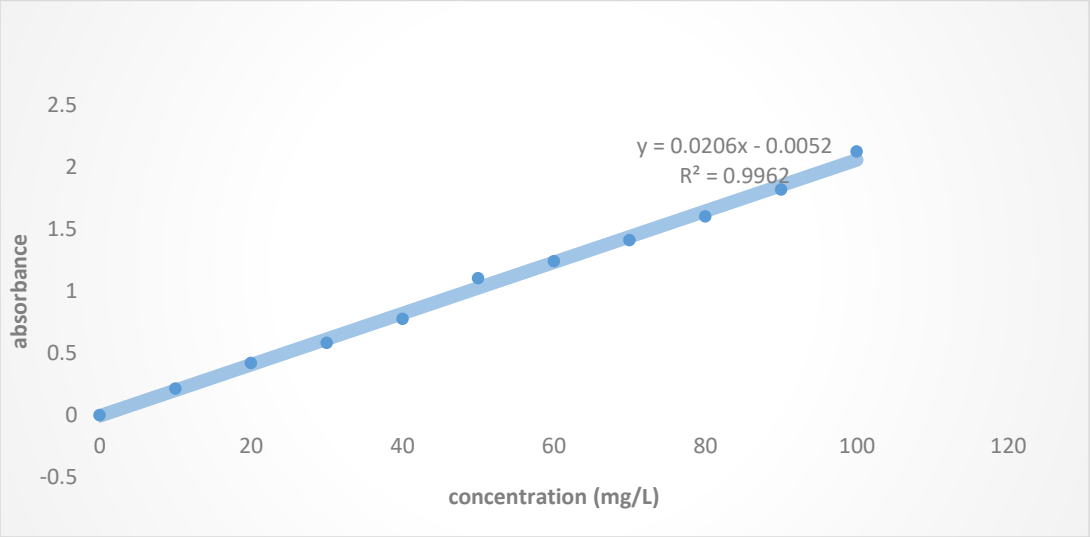


Figure 3: UV-visible Spectroscopy Calibration Curve for Methyl Orange

Effect of Adsorbent Dosage on Removal of Methyl Orange

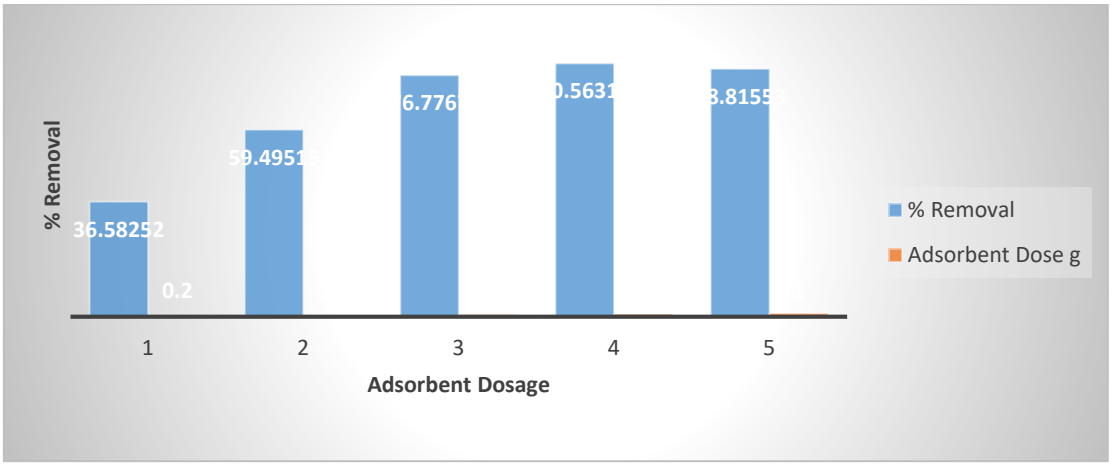


Figure 4: Effect of Adsorbent Dosage on Removal of Methyl Orange

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

As shown in Figure 4 the adsorbent dose of 0.8 g gave the highest percentage removal (80.56%) for methyl orange followed by 1.0g HRB dose with 78.82% removal efficiency while the least was an adsorbent dose of 0.2g with percentage removal efficiency of 38.58%.

Relationship between Qe and Adsorbent dose

The equilibrium adsorption capacity (Qe mg/g) is generally inversely proportional to the adsorbent dose under constant initial concentration Co and adsorbate concentration as applied in this experiment. This is illustrated in Fig 5.

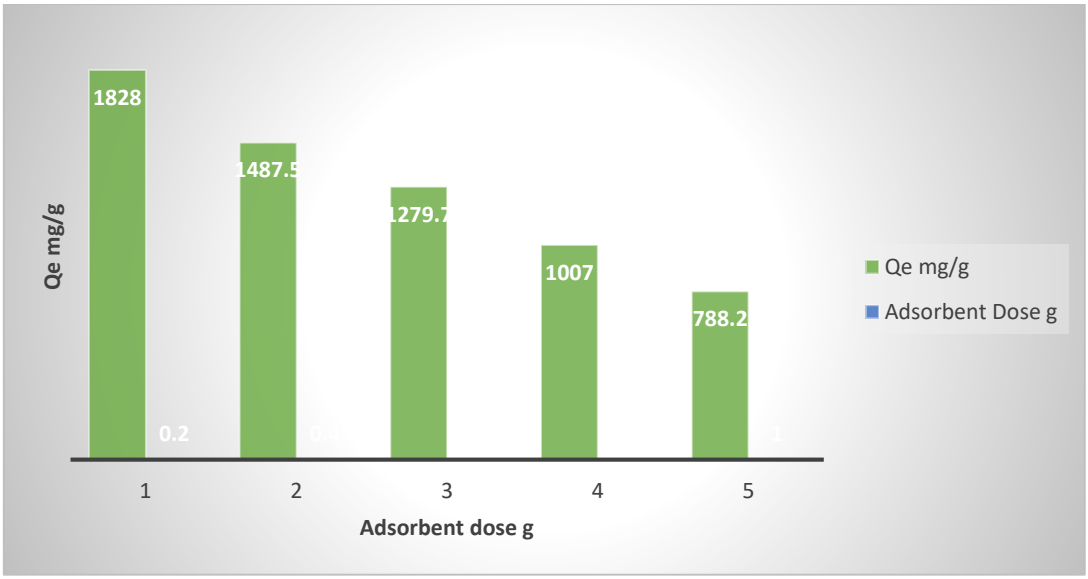


Figure 5: Relationship between Qe and Adsorbent dose

Effect of time on Percentage Removal of Methyl Orange

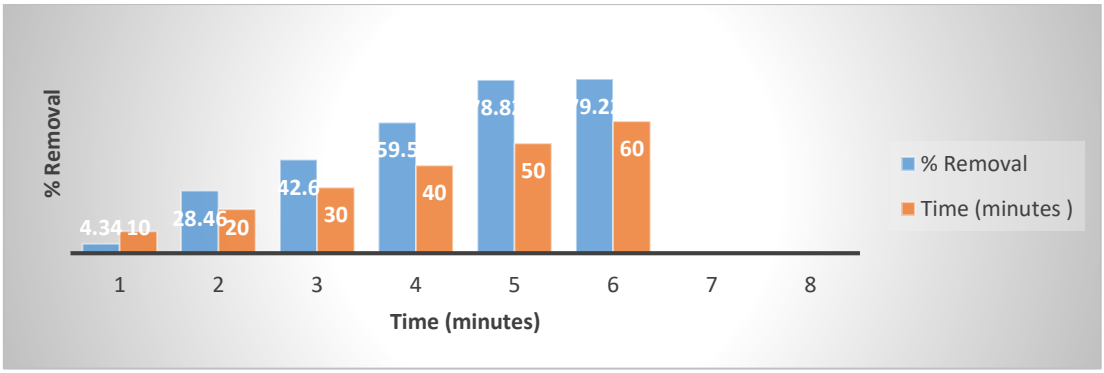


Figure 6: Effect of time on Percentage Removal of Methyl Orange

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

As illustrated in Fig 6 the percentage removal efficiency of MO using the biochar kept increasing from 10 minutes from 4.34% until it reached a maximum at 60 minutes with a percentage removal efficiency of 79.22%.

Relationship between Qe and Time

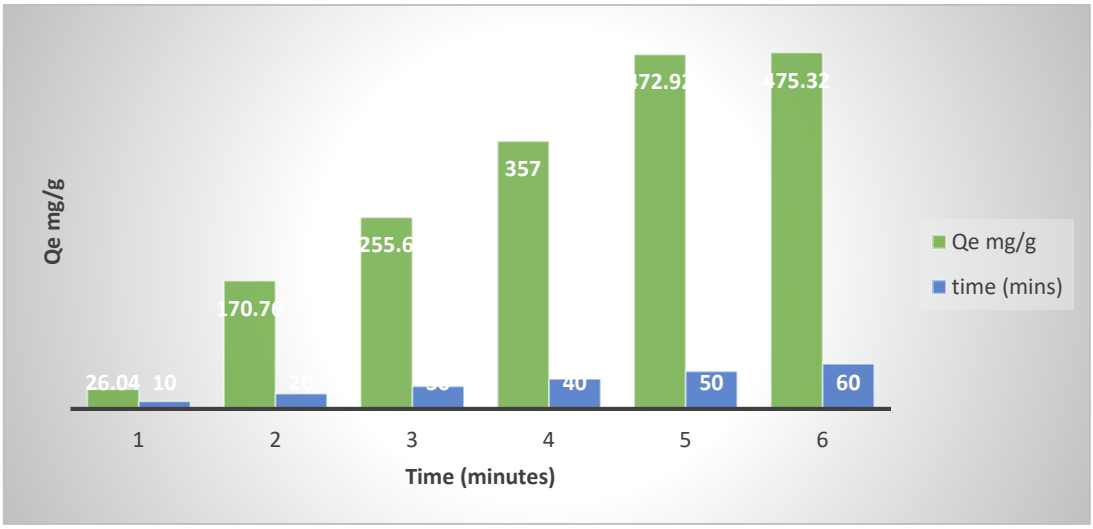


Figure 8: Relationship between Qe and Time

From Fig 8 as the time increases the maximum adsorption capacity also increases.

Langmuir Isotherm

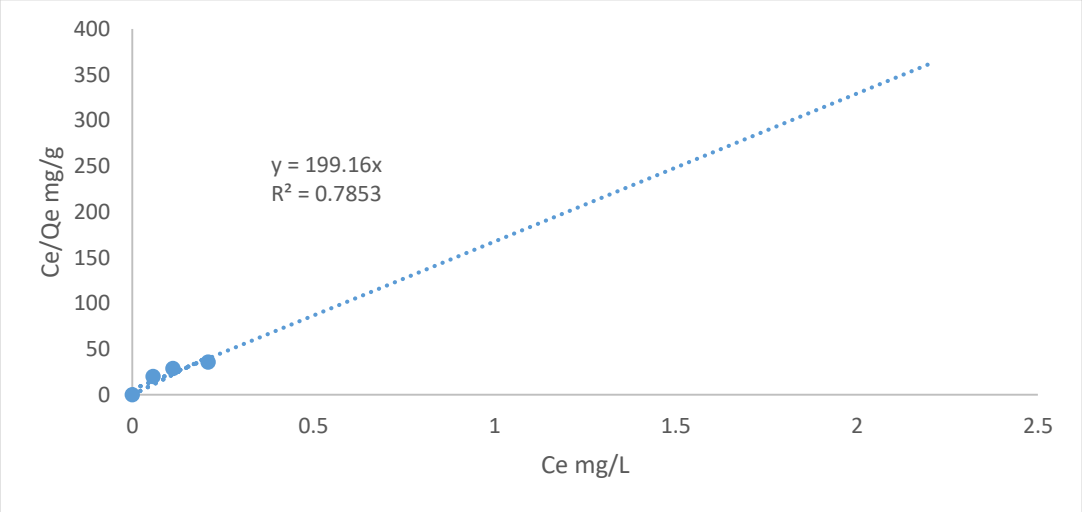


Figure 9: Langmuir adsorption isotherm for methyl orange

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

From the Langmuir isotherm equation aL=0.0062, kL=24.85 and R=0.866. R value lessthan 1 indicates that the sorption process for methyl orange was favourable.

Freundlich adsorption isotherm for methyl orange

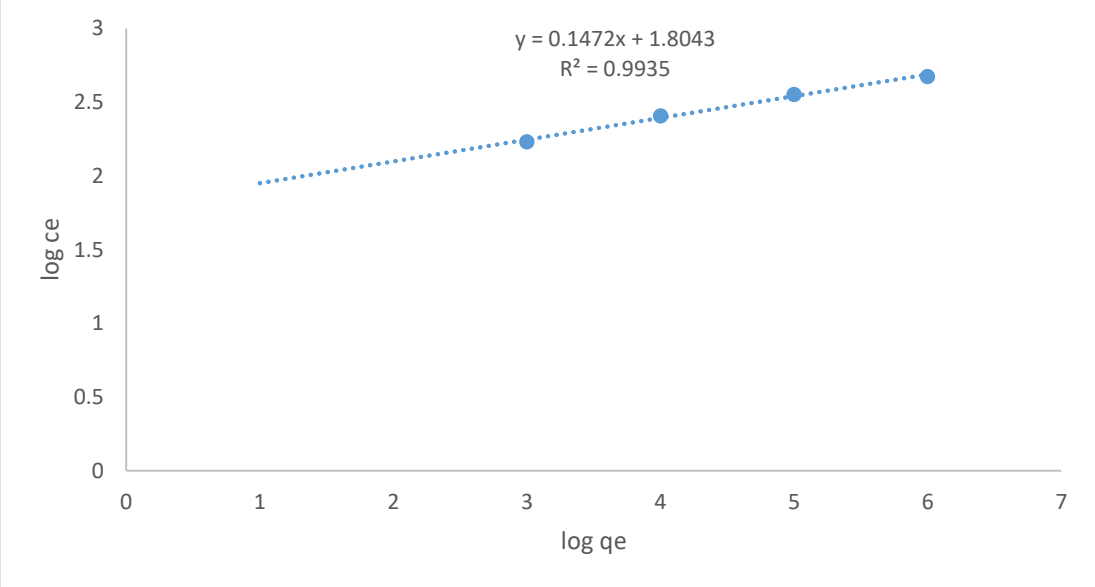


Figure 9: Freundlich adsorption isotherm for methyl orange

The n value and Kf were found to be n=6.793 and Kf=63.72. 1/n= 0.1472 which is less than one making the sorption process favourable.

Conclusion

The utilization of hibiscus flower juice residue to produce biochar for the adsorption of dye from wastewater could serve as a sustainable use of waste to produce a valuable product. The adsorbent gave a very high yield (93.26 %) when pyrolyzed at 500°C. Other proximate and ultimate data obtained exhibited that the biochar had a high fixed carbon content of 73.01 % which indicates low volatile matter and an increase in porosity that may aid adsorption. Mechanism of adsorption of biochar for methyl orange was through physical properties such as hydrogen bonding and dipole-dipole interactions. Chemical sorption occurs through ionic interactions by oxides of cationic elements (K, Na and Mg). The adsorption process was fitted into a Langmuir isotherm model for monolayer adsorption and Freundlich adsorption isotherm model for multilayer application.

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

The R and n values for both models indicated that the adsorption process was favorable.

References

Alegbe, E. O., & Uthman, T. O. (2024). A review of history, properties, classification, applications and challenges of natural and synthetic dyes. *Heliyon*, *10*(13), e33646. https://doi.org/10.1016/j.heliyon.2024.e33646

Al-Tohamy, R., Ali, S. S., Li, F., Okasha, K. M., Mahmoud, Y. A. G., Elsamahy, T., Jiao, H., Fu, Y., & Sun, J. (2022). A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety. *Ecotoxicology and Environmental Safety*, *231*, 113160. https://doi.org/10.1016/j.ecoenv.2021.113160

Cheng, H., Liu, Y., & Li, X. (2021). Adsorption performance and mechanism of iron-loaded biochar to methyl orange in the presence of Cr6+ from dye wastewater. *Journal of Hazardous Materials*, *415*, 125749. https://doi.org/10.1016/j.jhazmat.2021.125749

Danesh, P., Niaparast, P., Ghorbannezhad, P., & Ali, I. (2023). Biochar production: Recent developments, applications, and challenges. Fuel, 337, 126889. https://doi.org/10.1016/j.fuel.2022.126889

Ding, W., Dong, X., Ime, I. M., Gao, B., & Ma, L. Q. (2014). Pyrolytic temperatures impact lead sorption mechanisms by bagasse biochars. *Chemosphere*, *105*, 68-74.

Hasan, H. M. A., & Alfotaisi, H. M. M. (2020). Adsorption of Phenol Red Dye by using Activated Carbon Prepared from Sea Grasses. *Chem. Res. J*, *5*, 1-10.

Lee, H., Fiore, S., & Berruti, F. (2024). Adsorption of methyl orange and methylene blue on activated biocarbon derived from birchwood pellets. *Biomass and Bioenergy*, *191*, 107446. https://doi.org/10.1016/j.biombioe.2024.107446

Lellis, B., Fávaro-Polonio, C. Z., Pamphile, J. A., & Polonio, J. C. (2019). Effects of textile dyes on health and the environment and bioremediation potential of living organisms. *Biotechnology Research and Innovation*, *3*(2), 275-290. https://doi.org/10.1016/j.biori.2019.09.001

Leng, L., Xiong, Q., Yang, L., Li, H., Zhou, Y., Zhang, W., Jiang, S., Li, H., & Huang, H. (2021). An overview on engineering the surface area and porosity of biochar. *Science of The Total Environment*, *763*, 144204. https://doi.org/10.1016/j.scitotenv.2020.144204

Natrayan, L., Kaliappan, S., Dheeraj Kumar Reddy, C. N., Karthick, M., Sivakumar, N. S., Patil, P. P., Sekar, S., & Thanappan, S. (2022). Development and Characterization of Carbon-Based Adsorbents Derived from Agricultural Wastes and Their Effectiveness in Adsorption of Heavy Metals in Waste Water. *Bioinorganic Chemistry and Applications*, *2022*, 1659855. https://doi.org/10.1155/2022/1659855

Nishat, A., Yusuf, M., Qadir, A., Ezaier, Y., Vambol, V., Ijaz Khan, M., Ben Moussa, S., Kamyab, H., Sehgal, S. S., Prakash, C., Yang, H., Ibrahim, H., & Eldin, S. M. (2023). Wastewater treatment: A short assessment on available techniques. *Alexandria Engineering Journal*, *76*, 505-516. https://doi.org/10.1016/j.aej.2023.06.054

Onyeukwu, O; Dibie, D; Njideaka, O & Akpolome, D (2023). Hibiscus sabdariffa -uses, nutritional and therapeutic benefits - A review. 8. 18-23. Journal of Bioscience and Biotechnology Discovery Volume 8(2), pages 18-23, April 2023 Article Number: 61AE0DCA1 ISSN: 2536-7064 https://doi.org/10.31248/JBBD2023.178

Roy, M., & Saha, R. (2021). Dyes and their removal technologies from wastewater: A critical review. *Intelligent Environmental Data Monitoring for Pollution Management*, 127-160. https://doi.org/10.1016/B978-0-12-819671-7.00006-3

Saghir, S., Pu, C., Fu, E., Wang, Y., Xiao, Z. 2022. Synthesis of high surface area porous biochar obtained from pistachio shells for the efficient adsorption of organic dyes from polluted water. Surfaces and Interfaces, 34, 102357. https://doi.org/10.1016/j.surfin.2022.102357

Satyam, S., & Patra, S. (2024). Innovations and challenges in adsorption-based wastewater remediation: A comprehensive review. *Heliyon*, *10*(9), e29573. https://doi.org/10.1016/j.heliyon.2024.e29573

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

Seow, Y. X., Tan, Y. H., Mubarak, N., Kansedo, J., Khalid, M., Ibrahim, M. L., & Ghasemi, M. (2022). A review on biochar production from different biomass wastes by recent carbonization technologies and its sustainable applications. *Journal of Environmental Chemical Engineering*, *10*(1), 107017. https://doi.org/10.1016/j.jece.2021.107017

Shinde, S; Wadhai, S; Prajapati, D; Tade, M & Singh, V. (2024). Hibiscus Sabdariffa: The Tropical Plant with A Wealth of Health Benefit, Int. J. of Pharm. Sci.,Vol 2, Issue 11, 1046-1064. https://doi.org/10.5281/zenodo.14209766

Shruthi, V. H., & Ramachandra, C. T. (2019). Roselle (Hibiscus sabdariffa L.) calyces: a potential source of natural color and its health benefits. In *Food bioactives* (pp. 169-190). Apple Academic Press.

Wang, J., & Guo, X. (2020). Adsorption isotherm models: Classification, physical meaning, application and solving method. *Chemosphere*, *258*, 127279. https://doi.org/10.1016/j.chemosphere.2020.127279

Weber, K., & Quicker, P. (2018). Properties of biochar. *Fuel*, *217*, 240-261. https://doi.org/10.1016/j.fuel.2017.12.054

Yagub, M. T., Sen, T. K., Afroze, S., & Ang, H. (2014). Dye and its removal from aqueous solution by adsorption: A review. *Advances in Colloid and Interface Science*, *209*, 172-184. https://doi.org/10.1016/j.cis.2014.04.002

Yaseen, D. A. (2025). Fundamental and mechanisms of adsorption processes for dye removal. *Engineered Biocomposites for Dye Adsorption*, 23-45. https://doi.org/10.1016/B978-0-443-29877-6.00003-2

Zubair, M., Mu'azu, N.D., Jarrah, N. *et al.* Adsorption Behavior and Mechanism of Methylene Blue, Crystal Violet, Eriochrome Black T, and Methyl Orange Dyes onto Biochar-Derived Date Palm Fronds Waste Produced at Different Pyrolysis Conditions. *Water Air Soil Pollut* **231**, 240 (2020).

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]