Research Paper

The Efficacy of Coffee Husks Biochar in the Adsorption of Methyl Red from Textile Dyeing Wastewater

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Abstract— Contamination of water has become a global problem in the twenty-first century due to the entry of both organic and inorganic toxins into the water system. Enormous amounts of wastewater are discharged into the environment from the dyeing processes. Because of their great chemical stability, industrial effluent from textile production combined with insufficient dye degradation results in significant water contamination. Dye-contaminated wastewater poses major health concerns, including cancer, as well as problems for the aquatic environment. A common azo dye used in textile manufacture and as an antibiotic is methyl red dye (MRD) which finds its way into the water system when directly released or stray during the dyeing process. It is known to be poisonous, carcinogenic, teratogenic, mutagenic, and cause respiratory issues. Therefore, it is crucial to keep an eye on the quality of water. There is a need therefore to remove these toxins from the environment and water. Coffee husks biochar (CHB) was produced by gentle pyrolysis of coffee husks at 350 °C followed by characterization using XRD, FT-IR, and SEM. Analysis using FT-IR revealed the vanishing of the O-H group in the coffee husks and the emergence of C=C, C=O, and C-O in the CHB indicating the conversion of husks to biochar. Besides, the SEM investigation demonstrated a change in the surface morphology of the CHB. In batch investigations, the impacts of CHB dose (0.2-1.2 g), medium pH (1-12), time of contact (5-60) minutes, and initial dye concentration (20-150 mgL^{-1}) were investigated. Coffee husks biochar demonstrated remarkable efficacy in eliminating MRD with an impressive removal efficiency of up to 96.56% at optimum conditions. At pH 2 and 0.6 g of CHB, an adsorption equilibrium capacity of 10.42 mg g^{-1} was reached in 25 minutes. Langmuir isotherm proved to be the appropriate model for describing the MRD adsorption onto CHB, assuming a chemisorption mechanism.

Keywords— Coffee husks biochar; methyl red dye; textile wastewater; Adsorption; removal efficiency; Adsorption isotherms

1. Introduction

Water plays a vital role in both the environment and human development. Globally, water quality is a critical issue as it affects human health, environmental sustainability, and economic development [1]. According to estimates, a global population of over 800 million people lack safe drinking water [2,3]. The case is even worse in Africa with over 411 million people without safe drinking water [4]. Several factors such as water pollution, population growth, climate change, and limited infrastructure make the quality of water vary worldwide[5]. According to a report published by Kenya's Ministry of Health in July 2022, the number of cancer cases in the nation is increasing. Among the major cancer risk factors reported was exposure to chemicals [6].

Aquatic contamination is becoming a global concern in the 21st century as a result of the increased disposal of both inorganic and organic pollutants into the aquatic environment resulting from urban development, industrial growth, and agricultural operations [7]. These contaminants include; chemical, microbiological, and thermal pollutants that result in the deterioration of the quality of water [1]**.** The chemical pollution resulting from these activities releases water polluted with heavy metals including; arsenic, chromium, mercury, and cadmium, [8] among others, as well as synthetic organic chemicals like dyes, pigments, herbicides, and pesticides which are harmful to living things at high concentrations [9].

Annually, more than 0.7 million tons of not less than 100,000 million known industrial dyes are produced [10]. The main industries releasing toxic dye compounds include; textile, fertilizer, rubber, paper, plastics, pharmaceuticals, cosmetics, and leather [11]. Around 50,000 tons of synthetic dyes are disposed into natural habitats annually as a consequence of roughly 10 to 15 percent of the colours used in the world's textile industries' dyeing processes failing to fully bond with the fabric [12].

The effluent discharged from the textile industries coupled with the incomplete degradation of available industrial dyes causes considerable water pollution due to their high chemical stability [13]. In some industries, conventional wastewater treatment methods are employed to eradicate some of these dyes. However, a portion of these textile dyes finds their way into the water system when directly released or stray during the dyeing process. Synthetic dyes particularly the refractory azo-dyes such as methyl red are the most harmful water contaminants known to irritate the digestive tract and the skin if inhaled or ingested [14]. It is also mutagenic when it goes through bioconversion forming 2-aminobenzoic acid and N-N-dimethyl-p-phenylene diamine in the presence of oxygen [14]. Moreover, the presence of methyl red in the aquatic environment blocks sunlight penetration into the water thus interfering with the photosynthetic activities of the aquatic ecosystem as well as posing breathing difficulties to marine life due to a decrease in dissolved oxygen [15]. Several studies have reported the application of conventional techniques to treat industrial effluents such as electrochemical methods [16], filtration membranes, anaerobic digestion, photocatalysis, and adsorption [17]. Among these techniques, adsorption has proven to be highly effective[7,18].

Most of the biomass needs to be modified to improve its adsorption efficiency and stabilize the material, among the most common methods include; acid and base modifications that pose an additional burden to the environment. The use of biochar has received great interest among researchers because of the existence of large amounts of functional groups containing oxygen [19] with an ability to be applied practically, economically, and efficiently for the assimilation of, antibiotics, heavy metals, as well as dyes from discharged effluent [19,20,21]. Coffee husks are among the by-products generated during coffee processing and disposed of improperly with no economic value[22]. The transformation of coffee husks into biochar could provide an acceptable value addition to this waste. Studies on the applicability of coffee husks biochar (CHB) for the adsorption of methyl red have not been reported. This study, therefore, explores the use of coffee husks biochar in adsorbing methyl red dye from textile wastewater.

2. Related Studies

Various approaches have been employed in the treatment of textile dyeing effluents, like; biodegradation [23], chemical precipitation, coagulation, electrochemical oxidation [16], membrane separation, ion-exchange, and adsorption [24]. Adsorption refers to the adhesion of either gas, liquid, or solute molecules on the solid's surface. It is a cost-effective technique that can efficiently separate a wide range of chemical compounds [25]. Different adsorbents have been exploited in the uptake of dyes from textile dyeing wastewater including; acacia wood sawdust biochar [26], eggshell waste [27], cow bones hydrochar [28], catalytic converter exhaust [29], and waste from coffee husks [12] among many other cellulosic materials.

Coffee production pollutes water, land, and air due to processing unit byproducts [30]. Coffee husks are high in nutrients, organic matter, hemicellulose, lignin and cellulose, caffeine, tannins, and polyphenol compounds. The presence of polyphenols compounds in coffee husks not only causes environmental pollution but also limits their use as animal feed [31]. Coffee husks have shown excellent adsorption capacities in wastewater treatment to remove cationic dyes and are cost-effective adsorbents because they are obtained from readily available raw materials [12].

Enhancing the sorbent through modifications improves its capability to adsorb organic contaminants like dyes [32]. Biochar produced through pyrolysis of biomass waste has potential application in wastewater treatment [33], due to high oxygen containing functional groups. Different biomass materials rich in lignocellulose such as bagasse, straw, stalks, and wood have been proposed for biochar production [34]. Factors such as temperature and time taken to pyrolyze various feedstocks determines the characteristics of the biochar [35]. Various biochars have been exploited for the purpose of removing textile dyes from wastewater including; chitin [21], rice straw [36], sugarcane bagasse [37], sawdust [26], and eucalyptus [35] among others. Biochars derived from agricultural wastes such as coffee husks are being considered as they may be applied for the elimination of contaminants without any activation and are readily available and recyclable.

3. Materials and Methods

Chemicals
Methyl red dye, acetic acid, sodium acetate, ammonium chloride, and ammonia solution of an analytical grade of purity (99.9%) were procured from Kobian Limited, an outlet of Sigma Aldrich in Nairobi, Kenya. To make a 1000 ppm MRD stock solution, 1.0 g of MRD was dissolved in a volumetric flask (1000 mL) using de-ionized water. By diluting the stock solution, the pertinent concentrations needed for succeeding batch trials were obtained.

Preparation of coffee husks biochar (CHB)
Dry coffee husks were randomly collected from the coffee processing unit at the Dedan Kimathi University of Technology, Kenya. They were then transported to the Chemistry laboratory, washed with double distilled water then exposed to sunlight to reduce the moisture content to less than 12%. Subsequently, the dried coffee husks were oven dried for one day at 60 °C as described by [38]. After being oven-dried, the coffee husks underwent a gradual pyrolysis at 350 °C for 60 minutes at a heat flow of 10 °C min^{-1} in a Carbolite CWF 1200C furnace. The CHB was then sieved to get the smallest particles, which ranged in size from 75 to 125 μm.

Coffee Husks Biochar Characterization
Surface morphologies of coffee husks biochar prior to and post loading with MRD were investigated by employing a Scanning Electron Microscope FEI ESEM (Tescan Vega LMH). Sputter coating was employed to coat the dry biochar

samples with a thin layer of conductive material which was then mounted on the microscope stage for scanning at an advancing voltage of 20 kV.

The existence of functional groups in the raw coffee husks and coffee husks biochar surfaces pre and post adsorption, were characterized by FTIR spectra (JASCO FT/ID-4700, Japan) spectrometer. The spectral analysis of raw coffee husks, and coffee husks biochar pre and post adsorption was conducted within the wave number range of 4000-500 cm^{-1}. The crystal structures of the raw coffee husks and the coffee husks biochar were analyzed using XRD Diffractometer (XRD, Rigaku Miniflex II, Tokyo, Japan) with a sample scan rate of 1º min^{-1} and sampling rate of 0.02º (2θ) with a scan angle of 2θ from 5º to 90º.

Batch Studies
To examine the impacts of different variables which included; pH, concentration, contact time, and adsorbent dosage, sorption experiments of MRD were carried out. All the tests were executed at room temperature to determine the optimal conditions for MRD removal. Adsorption parameters were varied as follows; dye solution pH (1 – 12), contact time (5 – 60 minutes), concentration of initial dye molecules (10 – 150 mg/L), and CHB dose (0.2 – 1.2 g) with a working volume of 50 mL.

All the batch tests were performed in replicate to increase the dependability of the results. The concentration of MRD was established by UV-vis using a wavelength of 520 nm.

Effect of pH
To examine the impact of pH on MRD uptake using CHB, a mass of 0.6 g of CHB was put in flask (250 mL) holding a 50 mL volume of 40 mg/L of MRD. To maintain the desired p levels, 0.1M acetate buffer was used for pH 4-5, while 0.1M ammonium buffer was employed for pH values above 6. The mixtures were then agitated at 200 rpm for 60 minutes, followed by filtration and analysis of residual concentrations by UV-Visible spectrophotometer.

Effect of contact time
The effectiveness of CHB in removing MRD was investigated by adding mass of 0.6 g of CHB to working volume solutions of MRD at 40 mg/L concentrations into an Erlenmeyer flask (250 mL) with subsequent stirring at 200 rpm in a range of 5 – 60 minutes. This was followed by filtration and analysis of residual concentrations by UV-Visible spectrophotometer.

The Effect of Concentration
The amount of MRD removal based on the initial dye concentration was studied by introducing 0.6 g of CHB into individual Erlenmeyer flasks (250 mL) holding solutions of 50 mL of MRD with working concentrations from 10 to 150 mg/L. The contents in the flasks were stirred at a speed of 200 rpm for the optimal predetermined time of 25 minutes. This was followed by filtration and analysis of residual concentrations by UV-Visible spectrophotometer.

The influence of Adsorbent Dose
The influence of CHB dose was assessed by introducing 50 mL of MRD solution with concentrations of 40mg/L to predetermined weighed amounts of CHB altered from 0.2 g to 1.2 g. The tests were performed at room temperature and at pH 2 and the mixtures were agitated at 200 rpm for the previously determined optimal time. The tests were performed in duplicate.

Adsorption Isotherms
Studies on adsorption isotherms were carried out for CHB in various MRD concentrations (10-150 mg/L) at room temperature. 50 mL of MRD solutions were added to 0.6 g of CHB in an Erlenmeyer flask (250 mL) at pH 2 and agitated at 200 revolutions per minute for 25 minutes. Modelling of experimental data was made successful by use of Langmuir and Freundlich adsorption isotherms (Equations 1 and 2) individually for the determination of optimal adsorption capacity and understanding the sorption mechanism. The isotherm model that yielded the highest correlation factor (R^2) and exhibited the best fit with the adsorption data was selected.

$$\frac{1}{q_e} = \frac{1}{K_L Q_{max} C_e} + \frac{1}{Q_{max}} \tag{1}$$

Where;

Q_{max} - optimum adsorption capacity,
C_e - equilibrium concentration, and
K_L - the Langmuir adsorption constant.

$$ln q_e = ln K_F + \frac{1}{n} ln C_e \tag{2}$$

Where;

q_e - the adsorbed solute,
C_e - the solute concentration,
K_F - a constant that indicates the adsorption capability of the adsorbent, and
$1/n$ - a constant that indicates the intensity that n can adsorb.

Textile Effluent
Textile wastewater samples were collected using 500 mL bottles from the Rivatex East Africa Limited Company in Moi University, Eldoret. The sample bottles were initially cleaned with detergent and then soaked in a 2 M concentration of nitric acid for four days. After this, the bottles were submerged in distilled water for 24 hours and then rinsed with a nitric acid concentration of 0.1 M. The temperature and pH of water samples were tested in situ. The sampled water was refrigerated at 4 °C awaiting analysis.

4. Results and Discussion

SEM Analysis
SEM images of powdered coffee husks before (a) and after pyrolysis at 350 °C (b) and after adsorption of methyl red dye (c) are shown in Figure 1 (a), (b), and (c) respectively.
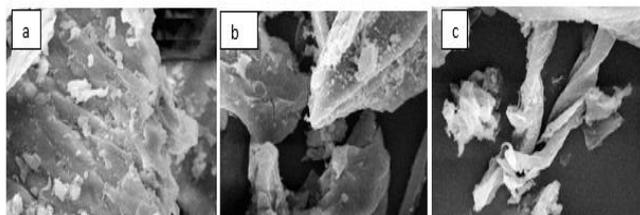
Figure 1: SEM images of Coffee husks (a), CHB (b), and CHB loaded with MRD (c).

The surface texture of coffee husks was rough, stiff, and constrained, as seen in Figure.1 (a). Coffee husk biochar was prepared by the heat action of the coffee husks, which led to the arbitrary distribution of sharp cracks, irregular pores, and fissures, as displayed in Figure.1 (b). The creation of holes and fissures that allowed for the adsorption of contaminants is linked to the emission of volatile materials during pyrolysis [39], [40]. The CHB also exhibited a crystalline structure that was attributed to cellulose and hemicellulose breakdown due to heat. The creation of long threadlike white patches on the surface of the biochar was seen after MRD was adsorbed onto CHB, as shown in Figure.1(c), and this was attributable to the occupation of the dye molecules on the porous exterior and inside the pores. Similar results were observed when the anionic dye was removed from wastewater using biochar made from waste [37].

FT-IR Analysis
The FT-IR spectra of coffee husks, coffee husks biochar (CHB), and CHB loaded with methyl red obtained in the wave number range 500-4000 cm^{-1} are displayed in Figure. 2.
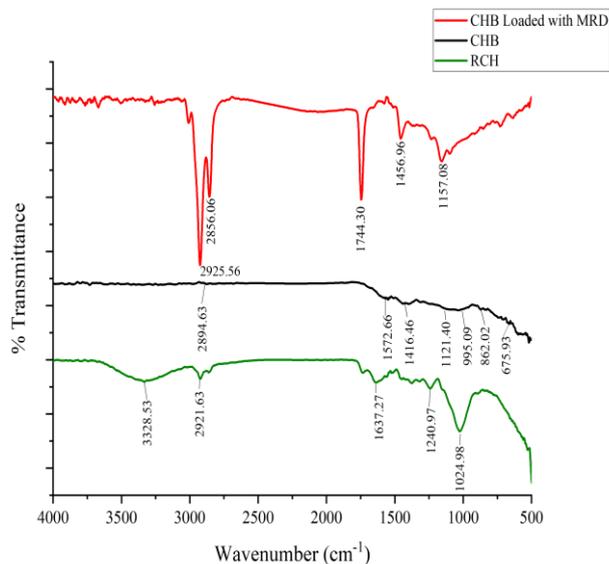

Figure. 2: Raw Coffee Husks, Coffee Husks Biochar, and CHB Loaded with MRD FT-IR Spectra

Raw coffee husks spectra presented bands similar to those displayed by lignin, hemicellulose, and cellulose. The peak at 3328.53 cm^{-1} in the raw coffee husks was ascribed to the stretching vibrations of hydroxyls. peaks spotted at 2921.63 cm^{-1}, 1637.27 cm^{-1}, 1240.97 cm^{-1}, and 1024.98 cm^{-1} were associated with asymmetric C-H stretching vibrations, OH deformation vibrations of adsorbed water, C-O vibrations of

carboxylic acid and its derivatives or phenolic vibrations, and asymmetric C-O stretching respectively [19]. It was observed that pyrolysis resulted in the modification of the intensities and the positions of the bands observed with the raw coffee husks. The band seen at 3328.53 cm^{-1} in the coffee husks attributed to hydroxyls, disappeared after pyrolysis indicating a reduction in oxygen content due to pyrolysis. Similar findings were reported by [34].

In the coffee husks biochar spectra, the aromatic C=C stretching vibrations were attributed to the peaks between 1640 and 1500 cm^{-1} [41], while the C=C bending at 862 to 645 cm^{-1} was linked to alkene groups [42]. A peak at 1416.46 cm^{-1} in the CHB was ascribed to the C-O stretching vibration of the carboxylate group on the biochar surface. A distinct band at 1024.98 cm^{-1} in the raw coffee husk associated with symmetric C-O stretching was shifted in intensity to a moderate band at 1121.40 cm^{-1} in CHB attributed to asymmetric C-O stretching [43]. This shift was a confirmation that lignin, cellulose, and hemicellulose present in the raw coffee husks were completely broken down and depolymerized during pyrolysis [19].

FT-IR analysis carried out on coffee husks biochar after adsorption of MRD showed a band at 2925.56 cm^{-1} linked with asymmetric C-H stretching vibrations [27]. A strong peak at 2856.06 cm^{-1} for CHB loaded with MRD was associated with either quaternary ammonium ($N^{+}(CH_3)$) stretching [44] or symmetric C-H stretching vibrations [45]. In addition, characteristic peaks were observed at 1744.30 cm^{-1} linked with C=O bending vibrations of carboxylic acid [44], and at 1456.96 cm^{-1} in CHB loaded with MRD may be linked to the C=C aromatic stretching. A medium peak at 1157.08 cm^{-1} was ascribed to asymmetric C-O stretching and or stretching vibrations of aromatic C-N in CHB loaded with MRD [34]. The formation of the C-N band at 1157.08 cm-1 signified the physical interaction between the amine group in the molecule of the dye and the carbon atoms on the CHB surface where the amine group acted as the electron acceptor and the biochar surface as the electron donor [38]. The modifications in the absorption spectra of CHB ensuing adsorption revealed the interactions of CHB functional groups with MRD.

X-ray Diffraction Analysis
The patterns of X-ray diffraction for RCH and CHB pyrolyzed at 350 ℃ are shown in Figure 3.

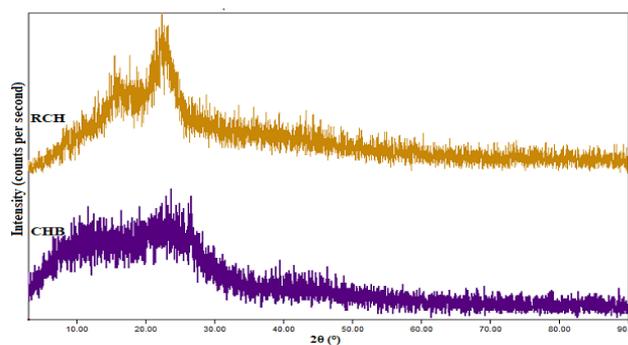**Fig. 3: RCH and CHB XRD Spectrum**

For the RCH a broad peak was observed at 2θ=22.65º relating to amorphous carbon resulting from carbon diffraction [46]. After pyrolysis, two distinct peaks were observed at 2θ=24.71 and 45.38º that corresponded to the amorphous carbon and graphite structure respectively [19]. The peak at 2θ=45.38º exhibits diffraction of hexagonal graphene carbons stipulating the appearance of aromatic structure in the biochar [41]. These findings agreed with the FTIR results.

Batch Experiment studies on MRD adsorption onto CHB
The study explored the impact of contact time, pH of the medium, dye initial concentration, and adsorbent dose. The findings were expressed in the form of removal efficiency as a percentage according to equation 3.

$$\%R = \frac{Co-Ce}{Co} \times 100 \qquad (3)$$
[47]

Here, C_o represents the initial dye concentration, and C_e denotes the dye concentration at the end of the process

Influence of pH
The influence of pH in the uptake of MRD was investigated in a range of pH of 1 to 12, CHB mass of 0.6 g, and 40 mg L^{-1} concentration at a residence time of one hour. Figure 4 illustrates the percentage of MRD removal with an increase in pH from 1 to 12.
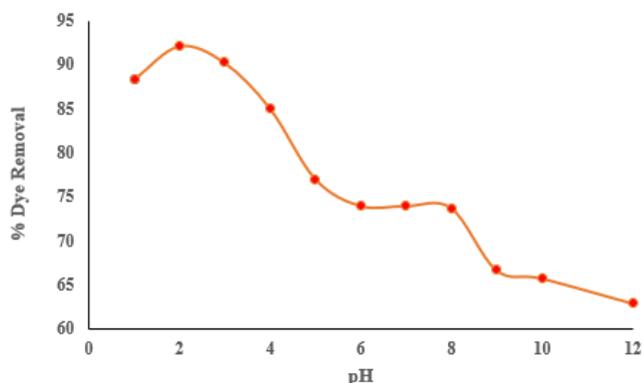

Figure. 4: The influence of pH on MRD adsorption on CHB

It was noted that at low pH the percentage removal increased to optimum at pH 2 (92.12%), thereafter a significant decline in the removal efficiency up to pH 5 (92.12 to 77.03%) was witnessed. From pH 6 to 10, a gradual decline in the removal efficiency was observed, with values stretching from 73.96 to 65.71%. A rise in the removal percentage with an increment in pH up to pH 2 is assigned to the static attraction among the cations on the solid surface and the anionic dye molecules *[48]*. The existence of hydroxide ions on the biochar's surface at higher pH above 7 resulted in competition among the dye molecules causing in a decline in the adsorption of the dye. It was evident that low pH favored the adsorption of MRD due to the existence of hydroxide ions in the dye media. Similar findings were reported by *[18], [27], [49]*.

Influence of Contact Time
The impact of contact time on the uptake of MRD by CHB was investigated by introducing a mass of 0.6 g of CHB into 50 mL of 40 mg L^{-1} MRD solution in a 250 mL flask. The results obtained are displayed in Figure 5.
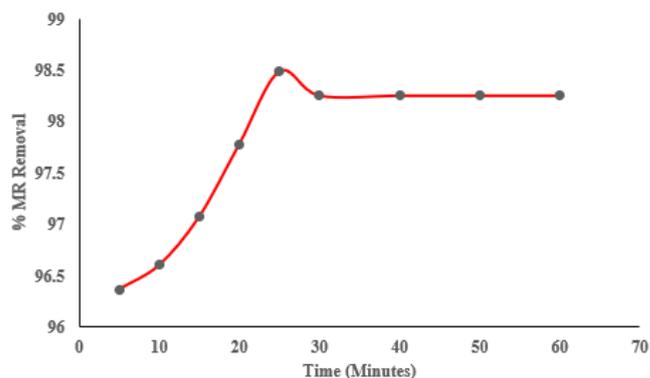

Figure. 5: The Influence of Contact Time on MRD Adsorption on CHB

The influence of contact time for the dye uptake was monitored in batch solutions at room temperature for 60 minutes. The optimum dye percentage removal (98.49 %) was attained within 25. There was no observable impact on the dye adsorption with the increase in time to more than 30 minutes indicating the attainment of a pseudo-equilibrium condition. A rise in the dye uptake at the infant stages was associated with the presence of highly accessible empty binding sites on the CHB [11]. Additionally, a rise in the dye molecules' collisions with the biochar increased the proportion of dye adsorption at the initial stages. Due to repulsion between the adsorbed dye molecules after impregnation of active adsorption sites, the vacant sites of the biochar are not able to adsorb any more dye molecules thus the curve flattens. Similar observations were reported by [36]. The suitability of CHB in the removal of MRD was demonstrated by the shorter contact times.

Influence of initial dye concentration
Various dye concentrations from 10-150 mg/L were investigated at optimal conditions of pH, time and CHB dose, and the outcomes are presented in Figure 6.
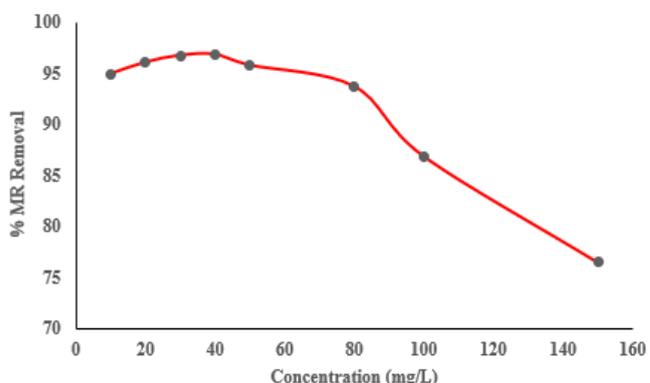

Figure. 6: Influence of initial dye concentration on adsorption onto CHB

The results show that, as the initial MRD concentration increases from 10 to 40 mg/L, a rise in dye removal proportion was registered from 94.91% to 96.84%. A rise in dye percentage removal with additional dye concentration can be linked to the occurrence of additional collisions between

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the biochar and the molecules of the dye [14]. After the active adsorption sites became saturated, there was a significant decline in the dye uptake leading to a decline in the proportion of dye removal. Competition among the dye molecules for the active adsorption site led to a decline in the dye removal efficiency at increasing concentrations. It was found that an addition to the initial MRD concentration led to a decline in the removal efficacy of CHB. Similar observations were reported in the uptake of acid orange 7 from an aqueous environment using Kenya tea pulps ash [11].

Influence of Adsorbent Dose
The influence of CHB dose in the uptake of MRD was tested by altering the CHB dose from 0.2-1.2 g at pH = 2, contact time = 25 minutes, initial dye concentration = 40 mgL-1, at ambient temperature. The outcomes are presented in Figure. 7.
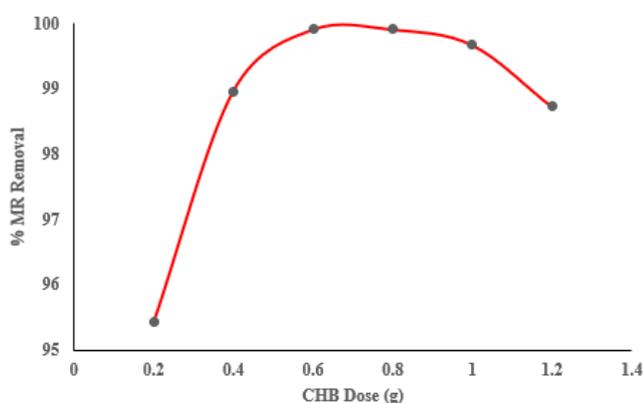

Figure. 7: Effect of CHB Dose on MRD adsorption

The results revealed that MRD decolorization was a function of the increasing adsorbent dosage owing to the availability of more vacant adsorption sites. Figure 7 shows that an addition of CHB dose from 0.2 to 1.0 g caused in a hike in the removal efficiency of MRD from 95.42% to 99.67%. An addition of CHB dose above 0.6 g resulted in an insignificant increase in the dye uptake with a slight decrease in removal efficiency observed beyond 1.0 g. An elevated percentage of dye adsorption was caused by the addition of new accessible vacant sites and a sizable surface area for the interchange of MRD molecules with the CHB [50]. In conclusion, 0.6 g of CHB was considered to be sufficient for an optimum removal efficiency (99.91%) of MRD from standard solutions in 25 minutes. Similar observations were made using eucalyptus biochar to remove crystal violet[35].

Adsorption capacity isotherms
Adsorption isotherms are applied to relate how the adsorbate and adsorbent interact. Equilibrium data and adsorption parameters are important in optimizing the suitable system for the adsorption of adsorbates from the solution [51]. To explain experimental data for MRD adsorption onto CHB, Langmuir, and Freundlich isotherm (equations 1 and 2) were employed. Equation 4 was used to calculate the number of adsorbed dye molecules in unitary mass of the CHB at equilibrium.

$$q_e = \frac{(Co-Ce)V}{M} \qquad (4)$$

Figures 8(a) and (b) show the plots of the Langmuir and Freundlich models while the adsorption isotherms parameters analysed using equations 1 and 2 are illustrated in Table 1.

Table 1: Freundlich and Langmuir Isotherm Parameters

Adsorbate	Langmuir				Freundlich		
	Q_{max} (mg g^{-1})	K_L (L mg^{-1})	R_L	R^2	1/n	K_f (mg g^{-1})	R^2
MRD	10.42	0.2447	0.0927	0.9925	0.3752	2.373	0.8948

The sorption of MRD onto CHB was well explained by Langmuir isotherm which gave R^2 (0.9925) compared to Freundlich isotherm with an R^2 value of 0.8948. The results revealed that adsorption behaviour of MRD onto coffee husks biochar was controlled by monolayer and homogeneous surface coverage and the sorption mechanism was explained by chemisorption. The optimum adsorption capacity of MRD computed from the Langmuir model was 10.42 mg/g. The values of R_L show the nature of Langmuir isotherm. According to Malviya[52], the isotherm nature is either favourable (R_L<1), irreversible (R_L=0), or unfavourable (R_L>1). In this study, the R_L values were 0.0927 confirming that the CHB was favourable for the adsorption of MRD. Similar findings were reported when cationic BR29 and RR2 anionic dyes were adsorbed on sawdust biochar [26]. 1/n is a Freundlich constant that measures the adsorption potency and its deviation from unity indicates a heightened variability in the surface properties of the biochar, indicating increased heterogeneity [53]. For the present study, the values of 1/n were 0.3752, indicating that the adsorption of MRD onto CHB was favourable. Additionally, values of 1/n being below one could also imply that the adsorption energies decreased with an increment in the adsorbate concentration at the biochar surface accelerating the impregnation of the adsorption sites [38].
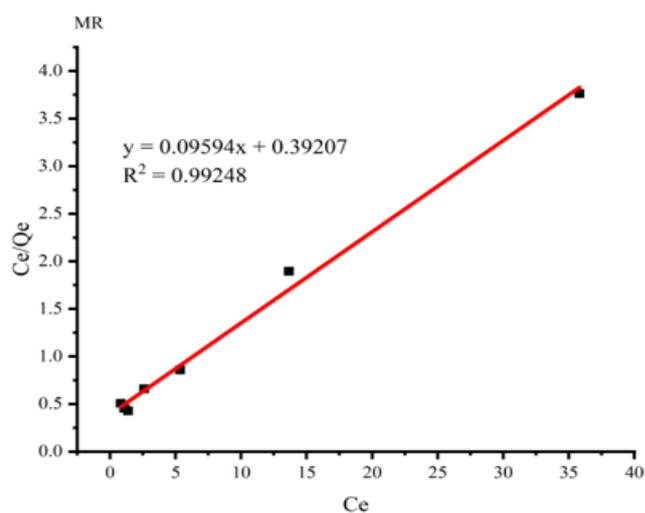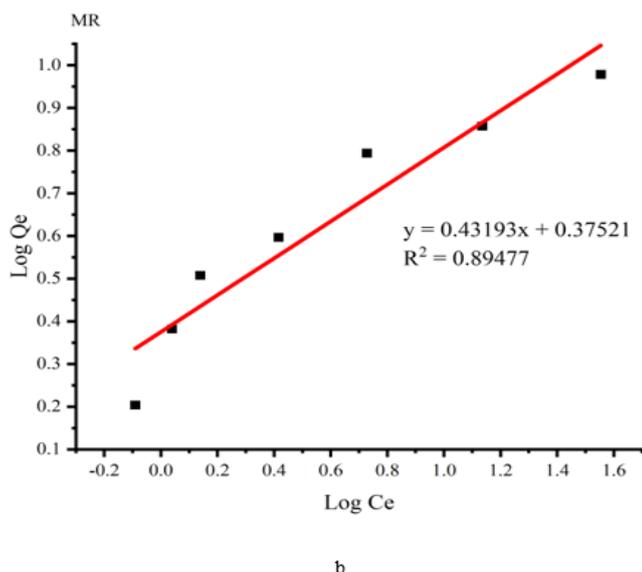

a

Figure 8: Langmuir isotherm (a), Freundlich isotherm (b) in a range of initial concentrations from 20-150 mg L^{-1} of MRD adsorption on CHB at room temperature

Adsorption of methyl red from textile effluent using CHB
At optimum conditions of pH 2, a residence time of 25 minutes, and, dose of CHB of 0.6 g, the textile effluents were subjected to adsorption using CHB. Under ideal conditions, the removal efficiency was 73.55% which was a bit lower compared to that obtained using standard solutions. This could be attributed to the existence of other anions and cations in the effluent competing for adsorption in the available adsorption sites on the CHB.

5. Conclusion

The efficiency of produced coffee husk biochar in adsorbing methyl red from aqueous solution was effectively tested. The SEM images confirmed that thermal action on raw coffee husks during pyrolysis resulted in the formation of sharp cracks, irregular pores and crevices that aided in the dye adsorption. The formation of white patches on the biochar surface after adsorption of MRD was an indication that the dye molecules occupied the porous surface as well as the biochar pores. The FT-IR of the raw coffee husks and the coffee husks biochar indicated the modification that took place during the pyrolysis of raw coffee husks. The disappearance of some functional groups such as hydroxyls (OH) and the appearance or shifting of C=O bonds, C-O, and C=C confirmed the modification of the coffee husks. The XRD characterization of CHB indicated the aromaticity of the coffee husks biochar (CHB) confirming the FT-IR results.

The adsorption of MRD on coffee husks biochar was influenced by the optimization parameters of pH, contact time, initial concentration, and dosage, with an optimum removal efficiency of 96.56% at pH 2, contact time of 25 minutes, a dosage of 0.6 g, and concentrations of 40 mg/L at room temperature. The acquired adsorption data fit well with the Langmuir model indicating that the chemisorption mechanism was engaged in the adsorption process. The removal efficiency of MRD from real textile effluent was 73.55% indicating that CHB is a potent low-cost adsorbent to eliminate MRD from textile wastewater.

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