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Efficacy of Moringa Oleifera Seed Husk as Adsorptive Agent for Trihalomethanes from A Water Treatment Plant in Southwestern, Nigeria

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Abstract:
Trihalomethanes (THMs) are formed when excess chlorine during chlorination of water reacts with organic material in water. They have mutagenous and carcinogenic properties. Moringa oleifera (MO) has found wide acceptance by many people in Nigeria who have used it for food for both humans and fauna, health purposes and as coagulant for water treatment. However, the seed husks are currently discarded as a waste and it has not been used as adsorbent to remove THMs from water. The physicochemical properties of both the treated and raw surface water were determined using standard methods and theconcentration of THMs were determined from the water treatment plant at different stages of treatment using gas chromatography with flame ionization detector (GC-FID). Recovery experiments were carried out to validate the procedure. The efficiencies of activated carbon of Moringa oleifera seed husk (MOSH) adsorbent for the removal of THMs in the water and as a coagulant for water treatment were also assessed. Batch adsorption experiments were carried out and different parameters such as pH (5, 7, 9), adsorbent dosage (0.2, 0.4, 0.8 g), contact time (30, 60, 90 minutes) and initial concentration (0.2, 0.4, 0.6 mg/l) were optimized for the removal of trichloromethane and tribromomethane using the MOSH activated carbon. Experimental adsorption data from different initial concentrations of trichloromethane and tribromomethane were used to test conformity with Langmuir and Freundlich adsorption isotherms. The percentage recovery from our procedures ranged from 96.0 ± 1.41 to 100.0±0.00 for trichloromethane while for tribromomethane the range was 60 ± 2.82 to 100.0±0.00. The mean percentage adsorption efficiencies for the simulation experiment ranged from 34.365 ± 1.41 to 93.135 ± 0.57 and from 41.870 ± 0.27 to 94.655 ± 0.41 for trichloromethane and tribromomethane respectively. The optimum conditions for both trichloromethane and tribromomethane were pH 9, 0.8g adsorbent dosage, 60 minutes contact time and 0.6 mg/l initial concentration. The optimum values of theses parameters used for the adsorption of the two THMs in the surface water serving the treatment plant gave efficiency of 100.00 ± 0.00 %. The turbidity values for the coagulation experiment reduced from 9.76 ± 0.03NTU in the raw water before coagulation to 5.92 ± 0.13 NTU after coagulation while all other physicochemical parameters of the surface water decreased in value except conductivity and total dissolved solid which increased from 104.5 ± 3.54 to 108.0 ± 2.83µS/cm and 63.00± 11.31 to 83.0 ± 8.49 mg/l respectively. The experimental data best fit into Langmuir than Freudlich adsorption isotherm. The study concluded that MOSH activated carbon could serve as adsorbent for the removal of THMs, calcium and sulphur from water samples.

Keywords: *GC- FID, Moringa Carbon, Trihalomethanes, Water.*

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1. INTRODUCTION

Agricultural waste is a biomass by-product that results from the agricultural processes which may include stalks, leaves, seeds, shells, peels, husks, and straws [1,2]. Agricultural waste also includes livestock and poultry waste. They are characterized by a wide range of source and large quantities. Due

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to their quantity and lack of proper waste disposal system, the wastes always constitute pollution to the environment [3,2]. At present, researchers are already looking into ways to sustainably turn these wastes into valuable resources. Agricultural by-products are converted to useful and value-added products. Studies have shown that agricultural waste can be employed in the generation of products that can serve as alternatives to the commercially available ones. For example, products like biochar, activated carbon/biochar, etc. have been reported to be produced from different agricultural waste and they find application for different uses such as in water and wastewater treatment thereby becoming another economic resource for agriculturists

Also, water treatment is necessary in this age of burgeoning human population, high demand for water resources and water reuse has surfaced in both urban and rural areas [4]. Portable water is becoming a scarce commodity and the treatment of available water with disinfectant for domestic water supply sometimes leave disinfectant by-products, such as (THMs). THMs had been found to be the most widely spread organic contaminants in drinking water and they are carcinogenic and sometimes mutagenic when ingested in high quantity.

Agricultural by-products are employed in water purification because the conventional methods available for treatment of water and wastewater are expensive, not environment friendly and sometimes cannot but leave by-products that may be of concern such as THMs. Adsorption has shown to be more efficient and cost-effective method for removing many pollutants [2]. Different agricultural waste have been used as adsorbent in the removal of pollutants. The agricultural wastes used include straw [5], wheat straw [6], bagasse [7], banana skin [8], walnut shell [9], coconut shell[10] and [11] etc. Among the many promising low cost materials that are possible to produce a biosorbent is the Moringa oleifera (MO), which its seeds has been used as coagulant and adsorbent for contaminants in water treatment. However, despite the increasing demand for MO plant for different purposes which leads to generation of waste such as the seed husk, there is paucity of data on the use of Moringa oleifera seed husk (MOSH) for removal of THMs from aquatic environment, hence this study.

2. MATERIALS AND METHODOLOGY

A. Preparation and Carbonization of Sample

The MOSH were collected from a local farm in Nigeria. The MOSH were washed, sun-dried and pulverized to increase the surface area for activated carbon production. Pulverized known weight (100 g) of the MOSHwas prepared by placing the raw material in a crucible, and incinerated in a furnace at 650ºC for 30 minutes and sieved to <150 µm particle size[12, 13].

B. Chemical Activation of the Carbon

The method is as outlined by [12, 13]. One hundred gramme (100 g) of the pulverized MOSH were soaked in 2% H_3PO_4 (v/v) for 48 hours, filtered and placed in an oven at a temperature of 110 ºC for 24 h. After cooling, it was washed with freshly distilled water to remove the residual acids until the solution reaches pH of 7 and used as an adsorbent.

C. Characterization of the Activated Carbon

The elemental composition and the surface morphological characteristics of the activated carbon were determined based on dry combustion method using Scanning Electron Microscope coupled with Energy Dispersive X-ray Analyzer (High resolution SEM/EDX-Carl Zeiss). Structural chemical functional groups in the activated carbon were determined using the Fourier Transform Infrared Technique (FTIR, Spectrum 100, Perkin Elmer).

D. Batch Adsorption Experiment of Simulated Polluted water

THMs polluted water were simulated in the laboratory by preparing a separate stock solution of Tribromomethane and Trichloromethane and diluted to varying degree of concentration (0.2, 0.4, 0.6

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mg/l). Batch adsorption studies were carried out using 0.2, 0.4, and 0.8 g of the adsorbent made from MOSH and 50 ml each of the simulated solution of THMs (Tribromomethane and Trichloromethane) polluted water in different conical flask with constant shaking using a shaker operated at 120 osc/min. The parameters such as pH, adsorbent dosage, contact time, initial THMs (Tribromomethane and Trichloromethane) concentration were optimized for successful adsorption. The batch adsorptions were followed by filtration using Whatman filter paper (No.1). The filtrates containing the residual concentration of the trihalomethanes under study were determined using Gas Chromatography (GC). The data obtained were subjected to paired sample T-test and one way analysis of variance.

E. Coagulation Test

The analysis of optimum dosage required of MOSH activated carbon was conducted following the jar test apparatus which is the method commonly used for simulating the coagulation-flocculation process [14, 15]. Two Conical flasks of 250 ml volume each were employed, filled with 200 ml of the water sample. The adsorbent dosage with the highest adsorption efficiency (0.8 g) during simulation experiment was used. The solutions were mixed rapidly for 2 mins, followed by 10 mins of gentle mixing using glass rod to aid the coagulation. The suspensions were left to stand without disturbance for 60 mins. The supernatants formed were decanted and subjected to turbidity, pH, conductivity, and total dissolved solids measurements. The turbidity was analysed with a direct reading turbidimeter (HACH 2100P) with precision of 0.01, while the pH, conductivity and total dissolved solids were measured using pH/EC/TDS Temperature meter.

F. Recovery Experiment for the Extraction Process and Determination of Trichloromethane and Tribromomethane

Liquid/Liquid extraction method (LLE) described by [16, 17] was adopted for the extraction of water samples. Acidified raw water (100 ml) spiked with 50 ml of 0.4 mg/L of Trichloromethane and Tribromomethane concentration of the standard mixture was extracted with 15 ml of dichloromethane (DCM). 2grammes of anhydrous sodium sulphate (Merck, Germany) were added to the collected extracts to remove the residual water. The collected extract was then concentrated to about 2 ml at room temperature for chromatographic clean-up according to the method of[17]. Recoveries of Trichloromethane and Tribromomethane standards were also investigated by spiking deionized water sample to check on the effect of matrix on extraction efficiencies. The equation of recovery experiment residual concentration is shown below [18].

$$\text{I\% } Recovery = \frac{spiked\ \ concentration\ \ - unspiked\ \ concentration}{spiked\ \ concentration}$$

3. RESULTS AND DISCUSSION

A. Physicochemical Parameters of Water Samples before Adsorption

The physicochemical parameters of raw surface and treated water samples before adsorption were carried out to determine the range of values of contaminants before and after the adsorption experiment. Al the parameters fall within the WHO limits (Table I). The results are presented in Table I and showed that parameter such as temperature, conductivity, Turbidity, Cl^- , NO_3^-, DO, TOC, BOD, and Alkalinity decrease in concentration after adsorption for both the raw and treated water while pH, total suspended solid and acidity showed decrease in concentration for raw water sample and increases for treated water.

B. Characterization of Activated Carbon

The results of the physicochemical parameters (carbon yield, the ash content, pH, and moisture content) of MOSH activated carbon are presented in Table II. The high percentage carbon yield from MOSH obtained makes it an asset compared to other agricultural wastes and fossil fuel sources [19] with low carbon yield because it can serve as one of the

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income sources of agro-based industries. High carbon yield and low ash content gives better characteristics of pore structures and this led to the established fact that high carbon yield of agricultural waste is indicative of good adsorption. Also from this Table 2, the pH of 5.8 is indicative of an acidic substrate. Activated carbon is usually amphoteric in nature and it implies it could be positively or negatively charged depending on the solution pH, in this case the solution pH will be positively charged. Attraction between activated carbon and anionic or cationic adsorbate is mainly related to the surface characteristics. More positively charged surfaces are obtained at lower pH values and this favours the uptake of more anionic groups due to increased electrostatic attraction between anions and the surface of the activated carbon [20].

Table I: Physicochemical Analysis of Influent Raw and Treated Water before and after Adsorption

S/N	Parameters	Units	Raw Water Before Adsorption	Treated Water Before Adsorption	Raw Water After Adsorption	Treated Water After Adsorption	WHO Standards Guideline Values
1	Temperature	^{o}C	27.6±0.14	27.15±0.07	23.6±1.55	26.11±1.12	25-32
2	Conductivity	µs/cm	104.5±3.54	108.5±0.71	89.5±3.53	102±1.41	2500
3	pH	-	6.8±0.00	5.64±0.12	6.5±0.14	6.6±0.11	6.5
4	TDS	mg/l	63.00±11.31	64.5±0.71	68.00±1.41	60.5±2.12	500
5	NO_2^-	mg/l	ND	ND	ND	ND	0
6	NO_3^-	mg/l	0.78±0.00	0.27±0.00	0.58±0.00	0.24±0.00	10
7	TSS	mg/l	2.87±0.00	1.67±0.00	1.9±0.03	1.81±0.20	100
8	Turbidity	NTU	9.76±0.03	1.84±0.24	5.03±0.39	1.03±0.08	5
9	SO_4^{2-}	mg/l	5.48±0.01	0.31±0.01	4.49±0.86	3.76±0.34	400
10	Cl^-	mg/l	25.85±1.91	7.26±0.41	12.69±1.61	3.29±1.37	250-1000
11	TOC	mg/l	5.78±0.00	4.33±0.08	0.64±0.02	0.41±0.05	25
12	BOD	mg/l	34.07±0.00	4.79±0.31	14.01±3.43	2.19±0.00	30
13	COD	mg/l	20.28±0.00	3.24±0.00	19.58±0.00	3.54±1.11	250
14	DO	mg/l	9.03±0.01	2.31±0.01	ND	ND	4-7
15	Acidity	mg$CaCO_3^{L-1}$	5.85±0.07	0.23±0.08	5.03±0.19	1.67±0.01	5.5
16	Alkalinity	mg/l	71.88±0.30	52.02±7.07	54.12±2.22	44.1±1.27	50
17	Trichloromethane (*M. oleifera* seed husk activated	mg/l	0.5395±0.033	0.255±0.086	Below Detection Limit	Below Detection Limit	0.3

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	carbon using GC-FID)						
18	Tribromomethane (*M. oleifera* seed husk activated carbon using GC-FID)	mg/l	0.5725±0.038	0.288±0.089	Below Detection Limit	Below Detection Limit	0.1

Table 2: Physicochemical Parameters of *Moringa oleifera seed Husk* Activated Carbon

Parameter	**Unit**	***Moringa oleifera* Seed husk Activated Carbon**
pH	-	5.8±0.36
Carbon Yield	(%)	81.8±0.43
Ash Content	(%)	4.2±0.55
Moisture Content	(%)	7.1±0.32

C. Elemental Composition of the Activated Carbon before and After Adsorption

The MOSH activated carbon was analysed using Scanning Electron Microscope coupled with Energy Dispersive X-ray (SEM/EDX) (High resolution SEM/EDX-Carl Zeiss) to determine its elemental composition before and after adsorption experiment (Table 3). The result shows that carbon has the highest percentage (45.5 and 91.51 and 95.51% respective before adsorption, and after adsorption for raw and treated) of all the elements present, and this makes it suitable for adsorption. This observation is in line with different studies that explains that carbon content tends to be high with high pyrolytic temperature using a one stage steam pyrolysis process[12, 21 and 22]. The disappearance of chromium after adsorption could mean that it has been introduced to the water samples thereby justifying the increase in conductivity and TDS values after adsorption (Table 1). The decrease in the percentage oxygen after adsorption could be attributed to utilization of oxygen to oxidise MOSH which is of organic origin. Also the occurrence of sulphur and calcium after adsorption in the activated carbon could imply that the activated carbon is also effective for the removal of calcium and sulphur from the water samples (Table 3).

D. Surface morphology of Moringa oleifera seed husk activated carbon before and after adsorption experiment

The surface morphological characteristic of the adsorbent is shown by the scanning electron micrograph. Fig. 1a shows the surface morphology of the activated carbon (adsorbent) before and Fig 1bi and 1bii after adsorption process. This explains the mass of particle and the surface morphology of the adsorbent. The surface of the adsorbent before adsorption shows wavy-like curves with perfect pore sizes which enables access into the internal pores. However after adsorption, it was observed that the pores were already clogged with the trichloromethane and tribromomethane contaminants adsorbed on the activated carbon indicating adsorption had taken place.

E. Functional Groups of Moringa oleifera seed husk Activated Carbon

The functional groups of the *Moringa oleifera* seed husk activated carbon were determined using Fourier Transform- Infra Red Spectroscopy (SHIMADZU-FTIR-8400S). Fig. 2 shows the functional groups present in the activated carbon of *Moringa oleifera* seed husk. Each of the bands on the FTIR represents a particular functional group which enables

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adsorption. The functional groups present are the Hydroxyl (3209.66^{-1} and 3059.20cm^{-1}), Carbonyl (879.57cm^{-1}), Aldehydes (759.98cm^{-1}), Ester (669.32cm^{-1}), Carbonate ester (1572.04cm^{-1}), Carboxyl (3209.66cm^{-1}), Ether (1139.97cm^{-1}) and Methoxy groups (2212.43cm^{-1}).

F. Batch Adsorption studies on Simulated Solution of Trichloromethane and Tribromomethane using MOSH Activated carbon as Adsorbent

The efficiency of MOSH activated carbon as adsorbent for the adsorption of trichloromethane and tribromomethane was investigated. The parameters (such as pH, adsorbent dosage, contact time and concentrations) affecting the adsorption were studied using the MOSH activated carbon. The results of the effects of each of the parameters are presented as follows:

a. Effect of pH on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment

The results of the investigation on the adsorption of Trichloromethane and Tribromomethane on *Moringa oleifera* seed husk activated carbon with varied pH (5, 7 and 9) are presented in Fig. 3 while all other conditions

Table 3: Percentage composition of the elements in Moringa oleifera seed husk activated carbon.

Elements (%)	**Before Adsorption Amount (%)**	**After Adsorption Amount (%) Raw**	**After Adsorption Amount (%) Treated**
Carbon	45.5	91.51	95.51
Chromium	3.0	-	-
Oxygen	10.0	3.50	3.53
Silicon	20.5	4.20	-
Zinc	31.0	-	-
Calcium	-	0.45	0.42
Sulphur	-	0.34	0.54

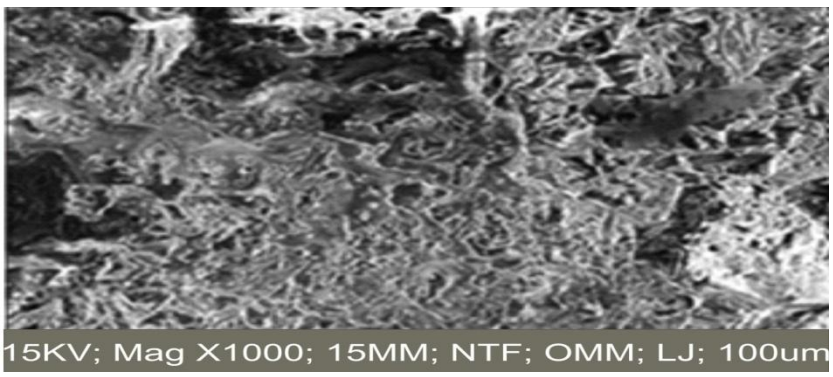

Fig. 1a: Scanning Electron Micrograph of *Moringa oleifera seed husk* activated carbon before adsorption

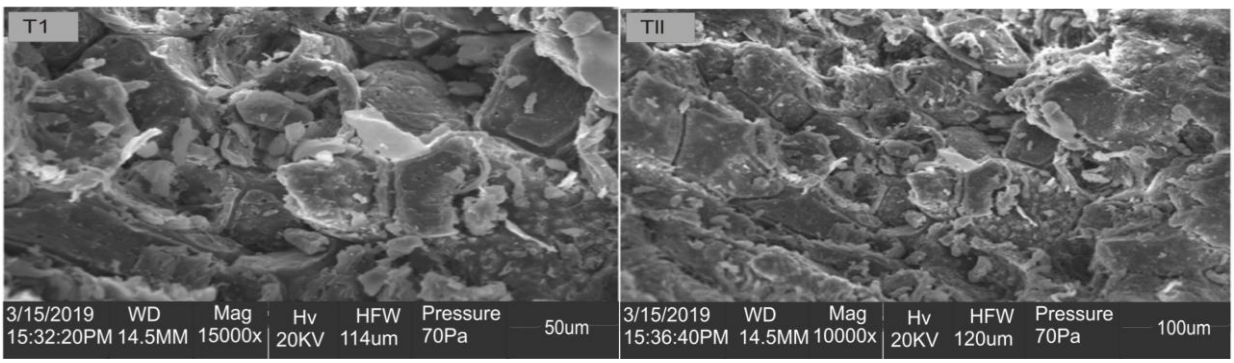

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Fig. 1b: Scanning Electron Micrograph of *Moringa oleifera seed husk* activated carbon after adsorption of Trichloromethane and Tribromomethane from Ti - treated water and TII - raw water samples.

(adsorbent dosage, contact time and concentration) were kept constant. The removal efficiency of trichloromethane was 90.5% at pH of 5, 58.65% at pH of 7, and 92.7% at pH of 9, while the removal efficiency of tribromomethane was 92.06% at pH of 5, 55.8% at pH of 7, and 94.95% at pH of 9. This trend may be due to the presence of hydroxyl bonds on the adsorbent as revealed in the FTIR results and it is in line with the report of [23 and 13]. This also shows that adsorption of THMs using MOSH activated can be optimal at both acidic and basic medium.

a. Effect of Adsorbent Dosage on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment

The result of different adsorbent dosages for the adsorption of trichloromethane and tribromomethane by *Moringa oleifera* seed husk activated carbon is presented in Fig. 4 while all other conditions (pH, initial concentration and contact time) were kept constant. The removal efficiency of trichloromethane was 53.64% at adsorbent dosage of 0.2 g, 71.35% at adsorbent dosage of 0.4 g and 73.68% at adsorbent dosage of 0.8 g, while the removal efficiency of tribromomethane was 44.1% at adsorbent dosage of 0.2 g, 71.93% at adsorbent dosage of 0.4 g and 76.80% at adsorbent dosage of 0.8 g. This shows that the efficiency of adsorption increases with increase in adsorbent dosage. This is because as adsorbent dose increases, free sorption surface and adsorption sites also increases and thereby adsorbing more trichloromethane and tribromomethane [24 and 25] . Adsorbent dose of 0.8g gave the highest removal efficiency for this study. However, from economic point of view, adsorbent dosage of 0.2g will be considered as the best dosage of MOSH activated carbon for this study.

c. Effect of Contact time on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment

The results of the adsorption of trichloromethane and tribromomethane on MOSH activated carbon by varying contact time (30, 60, and 90 minutes) are presented in Figure 4 while other conditions (pH, adsorbent dosage and concentration) were kept constant. The removal efficiency of trichloromethane was 70.17%, 76.27% and 75.83% at contact time of 30, 60 and 90 minutes respectively, while the removal efficiency of tribromomethane was 72.9%, 79.2%, 79.67% at contact time of 30, 60 and 90 minutes respectively. However, the equilibrium was set up at 60 minutes for the two THMs studied. This might be due to the initial availability of vacant sites for adsorption. The dynamic increment in adsorption and consequently the attainment of equilibrium adsorption may be due to limited mass transfer of THMs molecules from the bulk solution to the surface of the adsorbent [25]. A similar phenomenon was observed on the application of modified synthetic carbon for adsorption of THMs from water [26] and adsorption methyl parathion pesticides from water using water melon peel as low cost adsorbent according to [27].

d. Effect of Initial Concentration on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment

The results obtained from the investigation of the adsorption of trichloromethane and tribromomethane using MOSH activated carbon with varied initial concentration (0.2, 0.4 and 0.6 mg/l) are presented in Figure 5. The removal efficiency of trichloromethane increased from 33.37 to 54.74 and 76.14% at 0.2 to 0.4 and 0.6 mg/l respectively, while the removal efficiency of tribromomethane increased from 41.68% at initial concentration of 0.2 mg/l, 71.07% at 0.4 mg/l and to 81.98% at 0.6 mg/l. The

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two THMs removal efficiencies were observed to increase with increase in initial concentration. The highest adsorption efficiency was recorded for the two THMs concentration of 0.6mg/l while the lowest was observed at 0.2mg/l. This is in agreement with [25].

G. Adsorption Study on Influent Raw Water and Treated Water

Adsorption studies were conducted on raw surface and the treated water from the water treatment plant using MOSH activated carbon as adsorbent with the optimised conditions (pH -9, adsorbent dosage - 0.8 and 60 minutes contact time) from simulated experiments. The two THMs concentration of raw and treated water samples were determined using Gas Chromatography Flame Ionization Detector (GC-FID) and the concentrations were 0.5395±0.033 and 0.5725±0.038 mg/l for two THMs in raw water samples and 0.255 ±0.086 and 0.288±0.089 for the two THMs in treated water. The result of the removal efficiency of MOSH activated carbon for adsorption of Trichloromethane and Tribromomethane were below detection limit (0.00 mg/l) in both treated and raw water samples (as presented in Table 4) which implies 100% adsorption efficiency. This could be attributed to the fact that activated carbon produced from MOSH showed excellent performance in water treatment due to the high percentage adsorption efficiency. Also [26 and 13] reported that natural activated carbon removed a greater percentage of THMs in domestic water as well as wastewater.

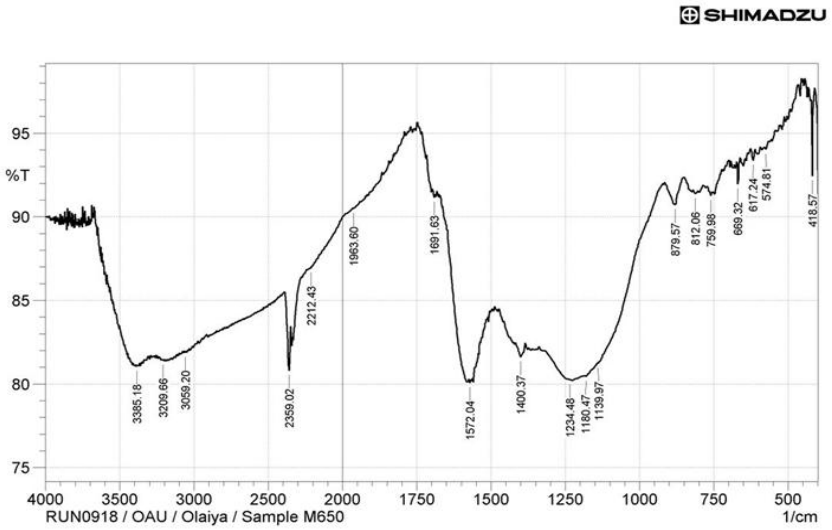

Fig. 2: FTIR Spectrum of *Moringa oleifera* seed husk Activated Carbon

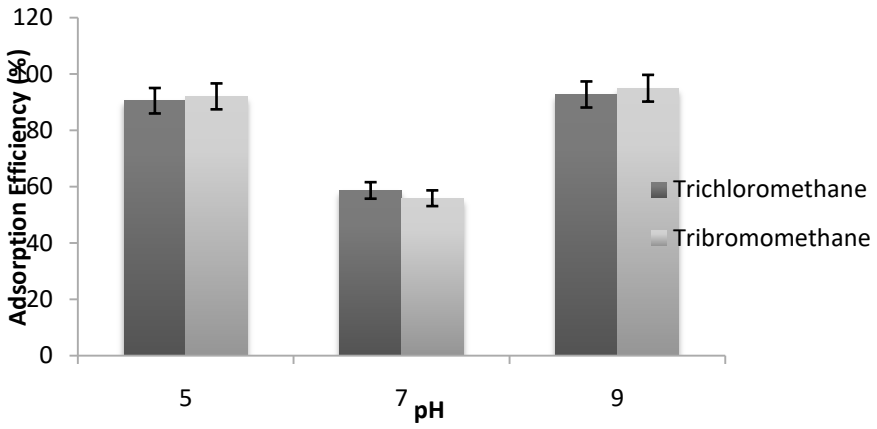

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Fig. 3: Effect of pH on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment.

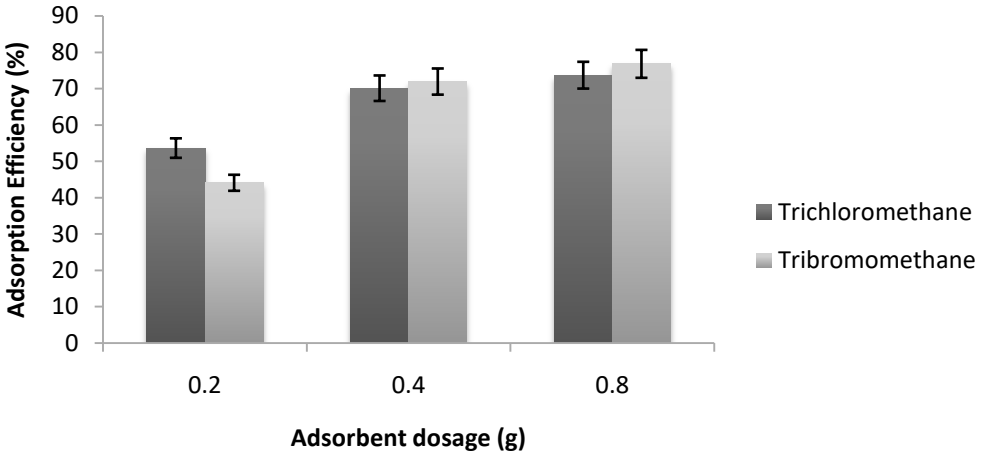

Fig. 4: Effect of Adsorbent Dosage on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment.

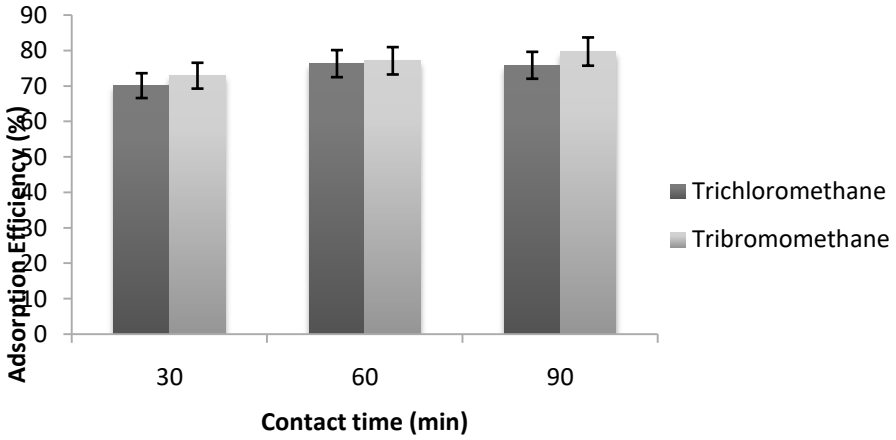

Fig. 5: Effect of Contact time on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment.

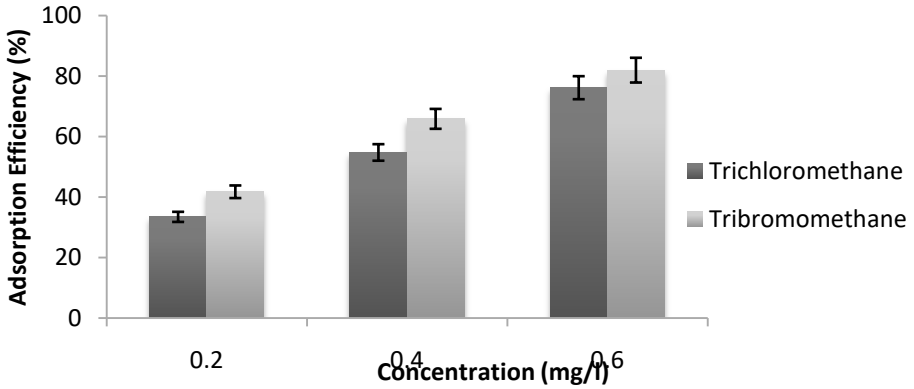

Fig. 6: Effect of Initial Concentration on Adsorption of Trichloromethane and Tribromomethane in Simulated Experiment.

Table 4: Adsorption Efficiency of *Moringa oleifera* seed husk Activated Carbon on raw and treated water

Contaminant	Adsorbent	Adsorption Efficiency (%)

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		Raw Water	Treated Water
Trichloromethane	*Moringa oleifera* seed husk Activated Carbon	100±0.00	100±0.00
Tribromomethane		100±0.00	100±0.00

Confidence level=0.05
Significant value=1.000

H. Evaluation of the Efficiency of Moringa oleifera Seed Husk Activated Carbon as a Coagulant for Water Treatment

The results of the evaluation of the efficacy of MOSH activated carbon coagulation test are presented in Table 4.

The results of the physicochemical investigation performed on the raw and treated water before and after coagulation test was presented in Table 5. It was observed that turbidity of the raw and treated water sample decreases after treatment. The turbidity value decrease from 5.92±0.13 to 4.92±0.52 NTU for treated water sample while the value for the raw water sample reduce from 9.76±0.03 to 1.84±0.24 NTU. pH value was also observed to decrease for raw water sample but increased in the treated water sample. Conductivity and TDS values were observed to increased for both the raw and treated water. Despite these trend observed in the result, the physicochemical parameter values were observed to be lower than the WHO standards. The result affirms the use of *Moringa oleifera* seed husk activated carbon as a coagulant to treat low turbid water.

I. Recovery Experiment for the Extraction Process and Determination of Trichloromethane and Tribromomethane

The results for the recovery experiment for the extraction process and determination of trichloromethane and tribromomethane is presented in Table 4.7. The percentage recoveries for the extraction of trichloromethane and 96±0.70 and 60±2.82 % respectively. However, in order to validate the extraction process, the deionized water was tribromomethane in raw water sample were 96±1.41 and 95±1.21 % while that of the treated water sample were spiked with a known concentration of trichloromethane and tribromomethane and the recovery percentage after the extraction process for the two THMs were 100% respectively. According to [17 and 16] recovery percentage yield of 100 and 90 % are considered to be qualitative and excellent yield, 50 - 80 % are considered good yield while 40 % below are considered to be poor yield.

4. CONCLUSION

MOSH show well-defined pores with large surface area which provides ample space for adsorption sites, therefore, improving the solute uptakes. Adsorption capacity of MOSH activated carbon was observed as excellent. The optimum condition that gave the highest efficiency for both trichloromethane and tribromomethane in this study are 0.6 mg/l concentration, adsorbent dosage of 0.8 g, contact time of 60 minutes and pH of 9. A conformation to the common adsorption isotherm models, Langmuir indicates that MOSH activated carbon is suitable for this adsorption. These study showed that agricultural waste, particularly MOSH to be one of the most promising activated carbon precursors.

RECOMMENDATION/ FURTHER WORK

Water treatment plants could use activated carbon developed from the waste husk of MO as adsorbent before and after treatment stage in addition to the known conventional water treatment processes.

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