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MORPHOLOGICAL CHARACTERIZATION OF BANANA PEEL POWDER AS A BIO-ADSORBENT FOR WASTE WATER TREATMENT

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Abstract— **This research work covers the morphological characterization of banana peel powder as an adsorbent for effluent treatment. The aim of this research is to analyze the morphological characteristics of the banana peel sample using BET, SEM, TGA, FTIR, XRD, proximate and ultimate characterization techniques. The banana peel sample was washed, sun-dried for three days, blended, and sieved to obtain fine powder before undergoing characterization. SEM images showed the rough microstructure of the sample. The TGA plot showed that the sample degraded at 270-350 ^{0}C and decomposed at 450 - 500 ^{0}C. FTIR spectra showed peaks of 3441.00 cm^{-1}, 2969.96cm-1, 2929.20cm-1, 2870.92 cm^{-1}, 1799.38 cm^{-1}, 872.86 cm^{-1}, 707.79 cm^{-1} and 366.38 cm^{-1}. The XRD diffractogram showed two major peaks at 2θ values of 12 and 28 degrees at intensities of 960 and 780 respectively. Ultimate analysis showed the values of carbon, hydrogen, oxygen, nitrogen, sulphur, and the calorific value as 65.50±0.3, 5.96±0.3, 10.80±0.2, 1.14±0.1, 0.80±0.3, and 20.62 respectively. Proximate analysis showed 7.60±0.4, 18.45±0.2, 30.70±0.4, and 43.45±0.7 for moisture, ash, fixed carbon, and volatile content. BET analysis showed that the sample had a surface area of 1065.435 m^2/g, pore volume of 0.150060 cm^3/g and pore size of 38.4041 A. In conclusion, banana peel powder can be used as a natural source of adsorbent that will benefit the society as a whole rather than being discarded as waste. This will not only conserve the environment, but it could also be a low-cost natural adsorbent.**

Keywords— **Low-Cost Natural Absorbent; Bio-adsorbent; Effluent Treatment; Morphological Characteristics; Ultimate Characterization Techniques**

I. INTRODUCTION

Activated carbons (AC) (both granular activated carbon (GAC) and powdered activated carbons (PAC)) are common adsorbents used for the removal of undesirable odour, colour, taste, and other organic and inorganic impurities from domestic and industrial waste water owing to their large surface area, micro porous structure, non-polar character and due to its economic viability (Nageeb, 2013). Banana peels can be used to purify drinking water contaminated with toxic heavy metals such as copper and lead. According to a study, researchers from the Bioscience Institute at Botucatu, Brazil, said that the banana peels could outperform even conventional purifiers such as aluminium oxide, cellulose, and silica, which have potentially toxic side effects and are expensive (Annadurai,etal., 2013). The team's method follows previous work that showed that plant parts, such as apple and sugar cane wastes, coconut fibres and peanut shells, could remove toxins from wastewater (Ashraf, et al.,, 2012). These natural materials contain chemicals that have an affinity for metals (Annadurai,etal., 2013). The peels are dried in the sun for a week, grounded and added to river water containing known concentrations of copper and lead (Annadurai,etal., 2013; Awual, et al., 2017). It was found that the peels absorbed 97 per cent of the metals are removed after just one hour. The peels were tested in the lab and worked perfectly (Bhatnagar, et al., 2019). Eventually, their efficiency reduces, at which point the metals should be removed from the skins so that they can be disposed of safely. Although the peels were tested only on copper and lead, the material could also work on cadmium, nickel, and zinc (Burakova, et al., 2018; Bhatnagar, et al., 2019). Researchers warned that this sort of filter is better suited to industrial purposes and cannot be used for water purification at home, as the extraction capacity of banana skin depends on the particle size of the heavy metals and this is difficult to measure (Elsalamouny, et al., 2017).

To the surprisingly inventive uses of banana peels which include polishing silverware, leather shoes, and the leaves of house plants, scientists have added purification of drinking water contaminated with potentially toxic metals (Essien, et al., 2015; Emaga, et al., 2017). Their report, which concludes that minced banana peel, performs better than an array of other purification materials (Fernandes et al, 2013 Essien, et al., 2015; Emaga, et al., 2017). It was observed that in mining processes and runoffs from farms, industrial wastes could all put heavy metals such as lead and copper into waterways (Fomina & Gadd 2014; Gueroult, et al., 2018). Heavy metals can have adverse health and environmental effects. Current methods of removing heavy metals from water are expensive, and some substances used in the process are toxic themselves (Josso, et al.,2018; King, et al., 2018). Previous work has shown that some plant wastes, such as banana peels, coconut fibbers, and peanut shells can remove these potential toxins from water (Gueroult, et al., 2018). Researchers found that banana peel quickly removes lead and copper from river water as well as, or better than, many other materials (Gueroult, et al., 2018). A purification apparatus made of banana peels can be used up to eleven times without losing its metal-binding properties (Essien, et al., 2015; Emaga, et al., 2017; Mohapatra, 2020). Banana peels are very attractive as water purifiers because of their low cost and because they do not have to be chemically modified in order to work (Vijayaraghavan & Yun, 2018).

Water is one of the most essential requirements for life. All living things need water for their survival. Water is used for a variety of purposes, including drinking, food preparation, irrigation, and manufacturing. Hence, it needs to undergo treatment before use. Although water covers more than 70% of the Earth’s surface, less than 1% of that resource is available as fresh water and this is not evenly distributed throughout the world (Mahindrakar & Rathod, 2018).. More than one billion people worldwide, mostly in developing countries, lack safe drinking water. Apart from the scarcity of water, there are many other challenges in providing a safe, adequate, and reliable water supply in many parts of the world (Anusha, 2017). Many technologies are in practice to treat the wastewater and in the present study; an attempt was made to investigate the application of natural adsorbent from banana peels for the treatment (Zhang, et al., 2005).

II. EXPERIMENT AND RESULT

*A.*Materials and Reagents

-Blender
-Sieve
-Distilled water
-Sample holder
-Sticky tape
-Electric weighing balance
-Thermometer
-Desiccators
-Heat source

*B.*Equipment used

The raw materials used in this research are the banana peels obtained from the Otuoke market in, Bayelsa state. The list of equipment and chemicals used are given below:

- X-ray diffractometer
- Thermo gravimetric analyzer
- Interferometer
- SEM equipment
- BELSORP-Mini-X sorption analyser
- Muffle furnace
- Element analyzer

C. Methodology

1) Sample preparation

The banana peels were collected, washed with distilled water, and sun-dried for 3 days. After drying, the banana peels were blended and sieved... The resulting fine powder was then subjected to characterization.

D. XRD analysis on sample

A very small quantity of the adsorbent (about one-tenth of a gram) was placed into a sample holder contained in the X-ray diffractometer. The sample was smeared uniformly onto a glass slide ensuring a flat surface. The sample was then packed into a sample holder and sprinkled on done sticky tape.

E. TGA analysis on sample

Thermo-gravimetric analysis of the sample was conducted using a thermo gravimetric analyzer. The sample was introduced manually into the TGA after being weighed by the integrated detection balance at 1.100 ± 0.05 g and then put into 12 crucibles containing four replicates of the sample. The average weight of the sample fed was 1.1572g. The sample was fed to the analyzer by an external autoloader and was ejected after the measurement, allowing for a high throughput. The resistance heated ceramic furnace programmed in 1^0C was heated from 50^0C to a maximum temperature of 900^0C at a gas flow rate of 70 ml/min and at a heating rate of 15^0C/min. The sample was characterized by thermal decomposition curves (under N2 flow) and combustion curves (under O_2 flow). The process was controlled via computer standard SOP software to investigate various thermo-gravimetric parameters. The experiment was run for a period of four hours and the curve plots for rise in temperature, percentage weight loss, and first derivative (rate) of the weight loss were plotted and displayed on the computer monitor.

F. FTIR analysis on sample

The sample was placed in a Fourier transform infrared spectroscopy (FTIR) which directed beams of Infrared at the sample and measured how much of the beam and at which frequencies the sample absorbed the infrared light. The sample was then identified by comparing its spectrum to a database, which houses thousands of spectra.

G. SEM analysis on sample

The scanning electron microscopy (SEM) was carried by placing a small portion of the sample in a metal stub using a two-sided adhesive tape and coated with a fine layer of gold using a sputter gold coater. Sample micrographs were observed at a magnification of 3000× at an accelerating voltage of 15 kV under a scanning electron microscope.

H. BET analysis on sample

The sample surface area was characterized using multipoint adsorption-desorption isotherm results at 77K with a Brunauer–Emmett–Teller (BET) model. The ASAP 2020 V4.02 (Micromeritics, US) analyzer used an equilibration time interval of five, no low-pressure dose, and an analysis bath temperature of 77 K. Prior to the BET analysis, the sample was subjected to degassing under a high vacuum at 350^{o}C for 4h.

I. Proximate analysis on sample

The proximate analysis was carried out using the method described by Speight. The parameters determined were moisture content, fixed carbon content, volatile content, and ash content.

1) Determination of Moisture content

In Accordance to ASTM D664, 5g of the sample was weighed into a period dish; the sample was charged into an oven and dried for 3hours at 100^{0}C. It was then collected, cooled in a desiccated for 15mins, weighed and charged into the oven again at 100^{0}C, the sample was collected cooled and weighed every 30mins until constant weight. The moisture content was then calculated

% moisture content = X 100

Where A=weight of Petri dish B=Weight of Petri dish + wet sample
C=Weight of Petri dish + dry sample

2) Determination of fixed carbon content

Fixed carbon is the solid combustible residue that remains after the sample is heated and the volatile matter is expelled. The fixed-carbon content of the sample is determined by subtracting the percentages of moisture, volatile matter, and ash content from the sample.
FCC = 100 - (MC + VC + AC)
Where FCC = Fixed carbon content and MC, VC and AC represent the moisture content, volatile content and ash content respectively.

3) Determination of volatile content

The volatile matter is the gaseous phase formed from the thermal degradation of the material. Take your sample in a crucible covered and put in furnace for 7mins until the furnace temperature reaches 950 degrees. After 7 min, keep out your sample from furnace and place in the desiccators for isothermal cooling. The weight loss of the sample represents the volatile content.

4) Determination of Ash content

For each of the sample 5g was weighed into a porcelain crucible separately; the crucible was placed in a muffle furnace and set to 450^{0}C for 3hours. The crucible and its content were cooled in desiccators and re-weighed. The weight of the residue as calculated below in percentage was recorded as ash content. (Food Safety and Standards Authority of India, 2012).

% ash content = X 100

J. Ultimate analysis on sample

This analysis is used determine the carbon, hydrogen, oxygen, nitrogen, and sulphur contents of sample according to the procedures outlined in European Standard EN 15104:2011 ("Solid bio fuels - Determination of total content of carbon, hydrogen and nitrogen - Instrumental methods"). The calorific value can also be obtained. For this analysis, the sample is combusted in an ultimate analyzer, which measures the weight percent of carbon, hydrogen, oxygen, nitrogen, sulphur, and calorific value from the sample.

K. SEM Analysis

Figure 1 shows the SEM images of banana peel powder under different conditions of magnification. SEM analysis according to Khan et al. (2015) is used to analyze the microstructure of the banana peel powder. Figure 1 shows that the banana peel powder has a rough, irregular, and uneven external surface with crater-like pores, which promote the adherence of toxic metal ions.

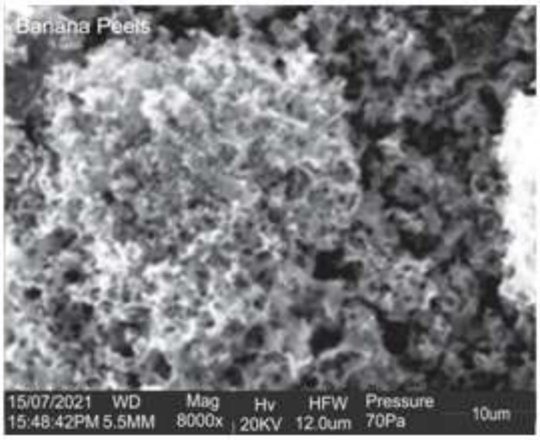

Figure 1a SEM images of banana peel

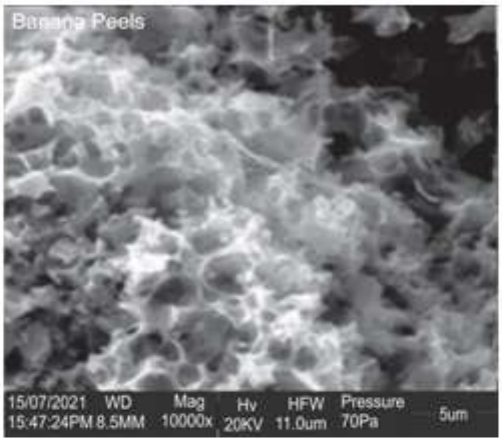

Figure 1bSEM images of banana peel

L. Thermo Gravimetric Analysis (TGA)

The outcomes of the thermo gravimetric analysis of the banana peels for weight loss and rate of weight loss at the temperature range of 50-500^{0}C are illustrated in Figure 2. This analysis involved three phases. In the first phase, dehydration of the sample occurred at 50-150^{0}C. The weight reduction in this phase was due to the elimination of the sample's moisture content (Chaiwong et al., 2013 and Biswas et al., 2016). However, there was thermal stability majorly due to the samples lower moisture content and exposure time (Fernandes et al., 2013). In the second phase, thermal degradation of the sample occurred as shown by the weight drop as illustrated in the graphs thus resulting in the least value in the Differential Thermal Analysis (DTA) plot curve (Sait et al., 2012). The average weight loss in this phase was approximately 50%, and this was because of the release of volatile matter contents. The final phase which was characterized by reduced weight loss at the solid decomposition stage and it occurred at temperatures between 450-500^{0}C (Chaiwong et al., 2013). At a heating rate of 10^{0}C/min, thermal degradation of the banana peel powder was initiated at approximately 150^{0}C with the maximum degradation occurring between 270^{0}C and 350^{0}C (Maia et al., 2014).

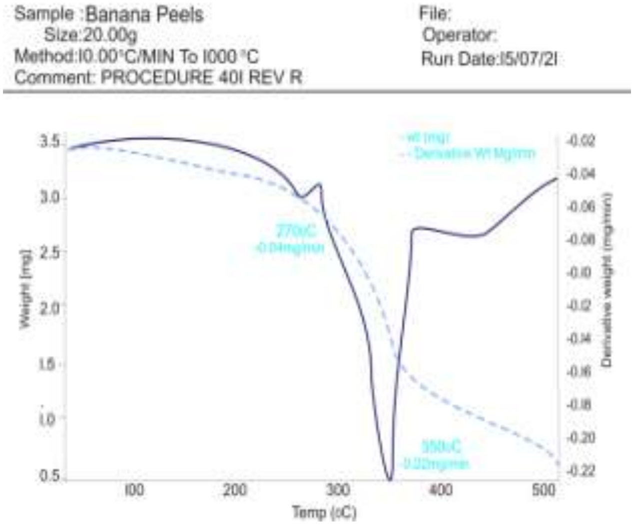

Figure 2 TGA plot for banana peel

M. Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectroscopy method was used to show the functional groups present on the surface of the banana peels. Figure 3 shows FTIR spectra of the banana peel powder. From the FTIR Spectra illustrated in Figure 3, there is band shifting and possible movement of OH group around the broad peak 3441.00cm−1 (Suresh, 2011). The peak at 2969.96cm-1 represents the stretching vibration of C=O bond of ketones, aldehydes and carbonyls. The peak at 2929.20cm-1 is due to the aromatic C=C vibrations usually found in carbonaceous materials. The peak at 2870.92cm−1 is due to CH stretching vibrations of CH, CH$_2$, and CH$_3$ groups (Chand, 2011). The peak at 1799.38cm-1 is due to the bending of C-O group in carboxylic acids, alcohols, and esters. The peak at 1427.00 represent carbohydrate CH group stretching's (Suantak, 2010). The peaks at 872.86, 707.79, and 366.38cm-1 all represent the characteristic bands mainly due to water deformation and carbohydrate (Khan et al., 2015).

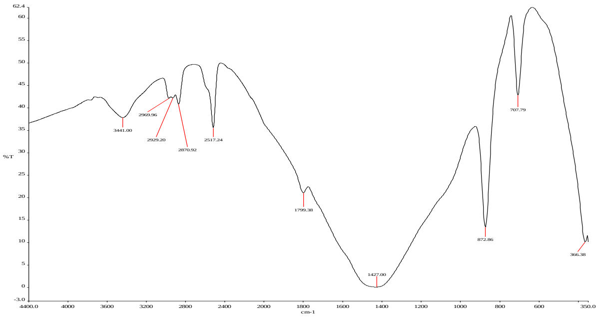

Figure 3 FTIR Spectra for Banana Peel

N. X-Ray Diffraction (XRD) Analysis

The X-ray diffractogram was used to study the nature of the banana peel powder at different developmental stages (Khawas, 2016). The diffractogram in Figure 4 showed two major peaks at 2θ values of 12 and 28 degrees at intensities of

960 and 780 respectively indicating a crystalline region. The width between the peaks is inversely proportional to the grain/crystalline size. The crystalline nature of the banana peel powder is an essential property for the efficient removal of toxic metals from effluents (Khawas and Sankar, 2016).

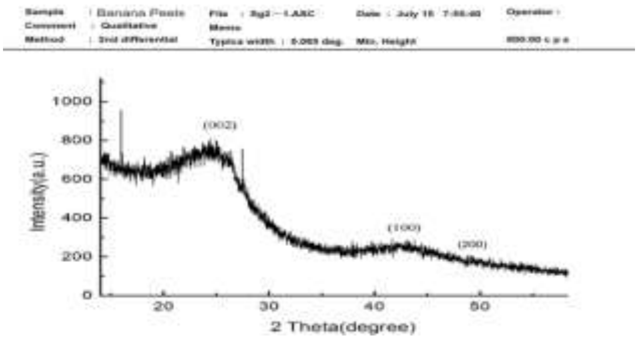

Figure 4 X-Ray Diffractogram for Banana peel

O. Ultimate Analysis

This analysis determines the presence of elements like Carbon, Hydrogen, Nitrogen, Sulphur, Oxygen, and calorific value. Table 1 shows the weight of carbon, hydrogen, oxygen, nitrogen, sulphur and the calorific value in percentage contained in the banana peel powder. It can be seen from Table 1 that the values of carbon, hydrogen, oxygen, nitrogen, sulphur and the calorific value which are 65.50±0.3, 5.96±0.3, 10.80±0.2, 1.14±0.1, 0.80±0.3 and 20.62 respectively agree appreciably with the literature values as shown in Table 1 (Mullen et al., 2014).

P. Proximate Analysis

Proximate analysis gives the nutritional value of banana peels as presented in Table 1. Proximate analysis gives valuable information on the nutritional composition and helps to access the quality of the sample. It provides information on moisture, protein, lipid, ash, fibre, and carbohydrate content.

1) Moisture content

This is the amount of water or moisture contained in the banana peel. From table 1, the average value of the moisture content was 7.60±0.4, which agrees appreciably with the literature value of 10.56 ±0.6 according to Mullen et al. (2014). The moisture content plays a significant role in determining the shelf life of the banana peel powder. According to Haussmann et al. (2010), products with lower moisture content, generally, are less subject to degradation by microorganisms and chemical changes.

2) Ash content

Ash is the inorganic residue remaining after water and organic matter has been removed by heating. Ash content is also the number of mineral elements in food. From table 1, the Ash content of the banana peel powder was 18.45±0.2, which agrees appreciably with the literature value of 16.28 ±0.22 according to Mullen et al. (2014). Similar observations were made by Emaga et al. (2013) who reported that the ash content in different banana peels varied from 12.8 to 22.3%. The values obtained in this study indicate that banana peel powder has energy value in the range of other fruit by-product (Morais et al., 2008).

3) Fixed carbon content

Fixed carbon is the solid combustible residue that remains after the banana peel powder has been heated and the volatile matter expelled. From table 1, the fixed carbon content is 30.70±0.4, which agrees appreciably with the literature value of 41.70±0.78 (Mullen et al., 2014).

4) Volatile content

This is the gaseous phase formed from the thermal degradation of the banana peel. From table 1, the value of the volatile content is 43.45±0.7, which agrees to a good degree with the literature value of 39.90±1.33 (Mullen et al., 2014).

Table 1 Proximate and Ultimate Analysis Data of Banana Peel

PARAMETERS	OBTAINED VALUES	LITERATURE VALUES
Moisture content	7.60 ± 0.4	10.56 ± 0.6
Volatile content	43.45 ± 0.7	39.90 ± 1.33
Fixed carbon	30.70 ± 0.4	41.70 ± 0.78
content	18.45 ± 0.2	16.28 ± 0.22
Ash content	65.50 ± 0.3	35.65 ± 0.21
Carbon	5.96 ± 0.3	6.19 ± 0.07
Hydrogen	1.14 ± 0.1	1.94 ± 0.16
Nitrogen	10.80 ± 0.2	12.94 ± 0.17
Oxygen	0.8 ± 0.3	1.5 ± 0.4
Sulphur	20.62	18.38
Calorific value		

Q. Brunauer-Emmett-Teller (BET) Analysis

BET characterization is aimed at determining the surface area, pore size, and pore volume of the banana peel powder. The BET analysis showed that the banana peel powder had a surface area of 1065.435 m²/g, pore volume of 0.150060cm³/g, and pore size of 38.4041 A. Figure 5 is a plot of the quantity adsorbed (cm/g STP) against relative pressure (P/Po). It can be seen from Figure 5 the adsorption between relative pressures of 0.01 and 0.02 is negligible. Actual adsorption started at a relative pressure of 0.1 and saturation occurred at 0.5. The distance between the relative pressures of 0.1 and 0.5 showed that the sample has the ability to absorb a large quantity of toxic metals before losing its potency.

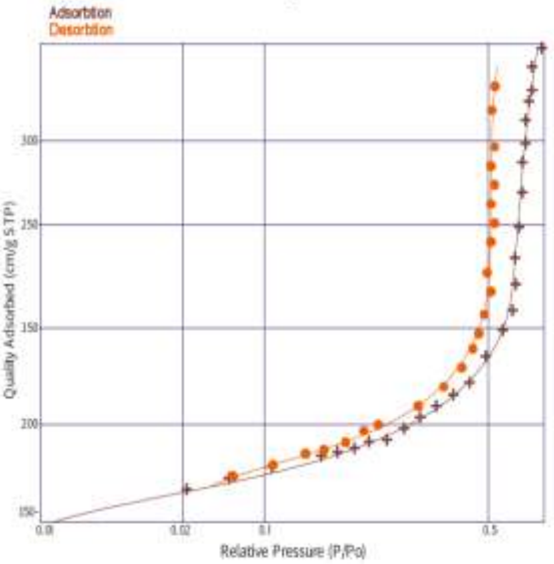

Figure 5 BET plot for Banana Peel

III. CONCLUSION

From the analysis carried out, the following conclusions were drawn. SEM analysis showed that the banana peel powder had a rough microstructure, which promotes adherence of toxic metals to the surface of the banana peel powder. TGA analysis showed that the banana peel decomposes between 450-500^{0}C which implies that it is still be used as an efficient adsorbent even at elevated temperatures. FTIR analysis of banana peel showed the presence of functional groups such as the carboxylic groups, which could play a major role in the adsorption of toxic metals. The crystalline nature of the banana peel powder as shown by the data on the XRD analysis is an essential property for the efficient removal of toxic metals from effluents. Proximate and ultimate analysis carried out on the sample gave a good idea of the nutritional value of the banana peel powder used in this study. By replacing the conventional synthetic media with cheaper alternative agricultural waste, it will save the production cost. The results of nutritional analysis suggested that banana peel could be the cheapest and most valuable bio-resource for effluent treatment. BET analysis showed that the banana peel had the ability to absorb a large amount of toxic metals before saturation, which makes it a favourable alternative for the removal of toxic metals from effluents. Banana peel powder can be used as a natural source of adsorbent that will benefit the society as a whole rather than being discarded as waste. This will not only conserve the environment, but it could also be a low-cost natural adsorbent.

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