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Adsorbent, dielectric and discharge characteristic properties of banana agricultural waste

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ABSTRACT

The Banana plant is one of the rapidly growing high biomass yielding plants. Banana agricultural waste such as stalks and leaves were combusted in the open air to eliminate the previous harvest. In this process, a significant amount of carcinogen causing compounds like polycyclic aromatic hydrocarbons (PAHs), black carbon and dioxins are being released into the environment. In this paper, we developed a controlled burning procedure to minimize the environmental pollution and leftover carbon waste is used for the absorption of dyes and the same is used for thermal and electrically conductive properties. Our results showed that a processed ash effectively decolorized the dye as similar to well-known compound graphite, which is evident from the spectroscopic and FT-IR analysis. It may be due to ion exchange between dye and ash. To understand the ion exchange we measured the DC conductivity by lab made four- probe method and the current was monitored with the help of a Keithley electrometer. This material displayed a good conductivity which is of the same level as commercial graphite. Taken together we conclude that the banana ash can be used as a biomaterial in the textile industry to remove the dyes and also can be used in electrochemical devices for battery applications.

Keywords: *Banana ash, Methylene Blue, FT-IR, Graphite, Conductivity.*

1. INTRODUCTION

Every year millions of tons of wastes are produced from different fields of sources like agricultural, municipal, and industrial sources. The possible pollutants from decomposing livestock compost include biological oxygen demand (BOD), pathogens, nutrients, methane, and ammonia emissions[1]. The uncontrolled decaying of organic solid waste can result in extensive contamination of soil, water, and air. Decomposition of 1 ton of organic solid waste can theoretically release 50–110 $m^3$of carbon dioxide and 90–140 m^3 of methane into the atmosphere. Biomass burning has a substantial impact on global atmospheric chemistry as it is responsible for huge sources of carbon monoxide, nitrogen oxides, and hydrocarbons. These gases are precursors of tropospheric ozone and affect the chemistry of the OH radical. Two prominent components of biomass burning are burning of wood, charcoal and agricultural waste as domestic fuel and the combustion of crop residue in open fields. The increasing world population leads to increase contributions from these types of biomass burning increases[2]. Billions of tons of agricultural waste are produced each year in the emerging and established countries. Agricultural waste consists of all leaves, straw, and husks left in the field after yield, hulls, and shells removed during processing of crop at the mills. The types of crop residue which play a major role as biomass fuels are relatively few.

Banana (Genus, Musa) plant is commonly grown all over the world. It is grown predominantly in tropical and subtropical countries. India contributes 14.37% of the world's banana production. Approximately $4.796x10^5$ ha of land is under banana cultivation in India yielding $16.37x10^6$t of banana. Each hectare of banana crop yields nearly 220 t of plant residual waste [3]. Most of these residual waste generated due to banana cultivation is discarded into adjacent rivers, lakes and on roads by farmers, which causes a severe ecological concern.

Banana is highly cultivated fruit across the world and 40% of the bananas are traded for consumption. Brazil is one of the largest banana growing industries with a total cultivation of up to 7 Mt, and remains the top exporter with a total of 185,721 t. This high value fruit is often wasted, it is estimated one fifth of the harvested bananas were often rejected and disposed due to poor post-harvest management practices[4]. Banana cultivation is prevalent in tropical and subtropical areas where many rural agricultural societies exist. Banana bears fruit only once in a lifetime, which requires 10-12 months from planting to harvest, leaving behind a substantial amount of reusable agricultural, remains. The current practice leaves this residue to decay in the field which causes spreading of diseases and polluting water supplies. In normal cases when the fruit is collected, the banana tree will be cut, leaving the bottom part of the stem and rhizome untouched for the new tree to grow from it. For every ton of bananas chosen, 10% (100 kg) of fruit is rejected and about 4 tons of wastes are produced, it means four times of wastes are generated in every cycle of production, which is wasted by either burning or by throwing them aside. There are many methods to consume the banana, starting from its fruits to till its wastes [5,6]. The fruits can be eaten raw, cooked, or processed to make candy or liquor. The rotten fruits and peels can be processed to feed poultry, pigs, and other animals. The pseudo-stems can be processed to make ropes, crafts, textile, paper, and boards. Every part of banana wastes can also be composted as fertilizer which is suitable for some vegetables. Banana wastes can also be a prospective source of energy. In India however, farmers only pick banana fruits for diet, and fresh leaves for food wrapping & used for food serving [5,7-9]. Other portions of the banana plant are dumped as wastes. Subsequently, farmers often are dumping the waste in banana growing areas. The aim of this work is to characterize banana plantation wastes through proximate, elemental, chemical, and thermal analysis, obtaining added value products. However, the study was limited to banana leaf and pseudo-stem only. Agricultural waste and their ash have shown to have many applications to maintain the clean air, water, and soil for the usage of the humanity. For example, the ash of the rice husk has shown to remove the phosphate from waste water[10] thermal insulations [11] CO_2 adsorption [12] and decolorization of methylene blue dye by agro-waste oiltea shell [13,14]. Similarly, lemon grass ash also has shown to adsorb methylene blue [15]. In this paper, we address the importance banana agricultural waste ash for dye adsorption properties and dielectric properties as compared to graphite.

2. EXPERIMENTAL SECTION

Materials. Graphite powder particle size of 60 mesh (Loba Chemi Pvt. Ltd.), Soxhlet apparatus, 10mm mesh cloth, Toluene, Acetone, Hcl, UV–Vis-NIR spectroscopy, Methylene Blue, and Magnesium metal.

Collection of Banana Ash. Stem and leaves of Banana burnt waste were collected from nearby agricultural lands which primarily grows banana plants near Vaddeswaram, Guntur district, Andhra Pradesh, India. The collected ash was subjected to purification/washing by soxhlet extraction using toluene followed by acetone, HCl & water to remove all soluble organic matter like aromatic hydrocarbons. After which the ash powder is dried in a hot air oven overnight at 45-50 ^{0}C as so called as processed ash for further biological applications.

Spectroscopic analysis of Dye Decolorization. To characterize the use of Ash in Textile Industry, we studied decolorization of methylene blue was monitored by UV–Vis-NIR spectroscopy equipped with a glass cuvette of 1.0 cm path length, with a scanning range from 400 to 800 nm. The concentrations of the residual MB in the solution were calculated at λmax = 664 nm.). In brief, 0.01 and 0.02g of ash & commercially obtained graphite (0.02g) were taken in a 15 ml polypeptide tube containing 1 µl of methylene blue (0.5 mg/mL). Then the samples were vortexed & centrifuged at 5000 rpm for 15-20 minutes. After centrifugation we have observed the decolorization of methylene blue hence the supernatant obtained was analyzed on spectrophotometer from 400-900nm. The ash/graphite pellet was washed with 18 mL of deionized water, dried and characterized using FT-IR

Determination of MB-Ash interaction using FT-IR analysis. To identify the molecular rearrangements of ash/graphite following methylene blue treatment, we recorded the infrared spectra with the help of a Perkin Elmer Alpha-E Spectrophotometer and heater coil of the furnace recorded in the wave number range 450-4000 cm^{-1}.

To study Dielectric and Discharge properties of Banana Ash. Dielectric studies are carried out on HIOKI 3532-50 LCR Heister Range 42Hz-50,000 MHz. Discharge characteristics were studied by fabricating a solid-state battery with the configuration of Mg^+(anode)/Processed ash/(I+C+electrolyte)/(cathode) for the prepared samples at ambient temperature for a constant load of 100 kΩ.

3. RESULTS SECTION

Methylene Blue Decolorization using Banana Ash. Here we compared the effect banana ash with commercial graphite as adsorbents to remove MB from aqueous solution and carried out the decolorization experiment under the same condition without absorbent. The resulting spectra were shown in Figure 1. As shown in Figure 1 (a), absorption of methylene blue was noticed between 500 to 700 nm and they are distorted peaks with a characteristic peak around 660 nm. Graphite has reduced the peak intensity and widened the Methylene blue peaks (Figure 1b). On the other hand, unprocessed and processed ash decolorized MB, which is evident from the significant drop of MB characteristic absorbance peak at 660 nm. Unlike graphite, ash and processed ash displayed absorption peak at 400-500 nm region. It may be due to the presence of different functional groups and their interaction with MB.

FT-IR analysis. To Study the interaction between methylene blue and ash, the samples were centrifuged, the pellet was used for FT-IR analysis. IR spectrum showed distinguishing characteristic peaks at four different regions (i.e, 4,000 to 2,500, 2,500 to 2000, 2,000 to 1,500, and 1,500 to 400). Graphite showed the spectra at 3448.18 cm^{-1}and, 2924.84 cm^{-1} represents O-H of a hydrogen bond or adsorbed water, 1626.67 cm^{-1} represent the characteristic peak of C=C bonds of the aromatic ring present in the graphite layers. The absorption bands at 1576 cm^{-1} can be ascribed to benzene rings [16]. In addition, the peaks at 1399 and 1021 cm-1 correspond to C-OH (hydroxyl) and C-O (epoxy) stretching vibrations of graphite respectively (Figure 2a). In MB treated samples, the graphite peaks such as 1399 and 1021 cm-1 were shifted to 1385 and 1110 cm-1 due to theinteraction between the adsorbent and the adsorbate of MB (Figure 2b). In comparison to graphite, Unprocessed Banana ash displayed differential peaks between 1800 and 1100 cm-1 region of IR spectrum. The peak at 1613.74, C=C or C=O stretching, 1417 cm-1, 1319 correspond to C-H in plane bending of cellulose. Many minor peaks at 876, 781, 659, 621, 514 and 469 cm-1 are the ‘fingerprint region’ that are characteristicof Banana Ash (data not shown). After chemical processing, certain peaks were shifted such as 1613.74 shifted to 1643.83 cm-1, 1319.74 shifted to 1384.15 cm-1 and certain peaks were disappeared such as 1417.22, 876.07, 659.35, 621.53, 514.33 and 469.23 cm-1. It suggests that the fingerprint region of ash such as Si-O-S stretching disappeared in processed ash (Figure 2c). On the other hand, the absence of a band at 1384.15 cm-1, corresponding to the adsorption of MB (Figure 2d). As methylene blue is a cationic dye, the –OH functional group on the surface of processed ash may increase the interaction between the adsorbent and the adsorbate, which contributes to the adsorption of MB. Our data is in accordance with previously published paper relate to Adsorption of Methyl Blue on Mesoporous Materials Using Rice Husk Ash as Silica Source [17].

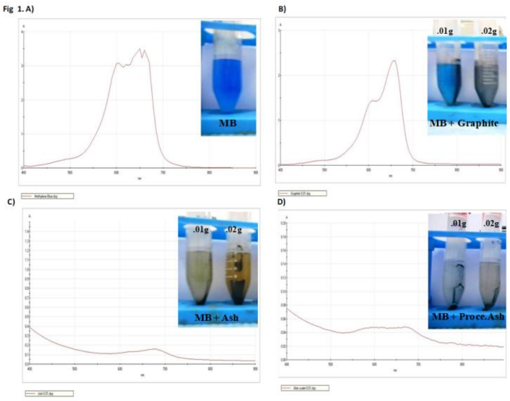

Figure 1. Spectroscopic analysis of (a) Methylene blue (b) Methylene blue + Graphite (c)Methylene blue + Ash (d)Methylene blue + Processed Ash.

AC-ionic conductivity. Cole Cole plots for plots for A and WA pallets at Room temperatures are shown in figure 3. Due to the electrode electrolyteinterference, a semicircle is obtained which relates the bulk resistance and a spike is obtained due to the polarization effect. Vertical spikes at the low frequency end should have been obtained, if the electrodes and electrode/electrolyte interface were ideal. Broadened semicircles and electrode spikes at the low frequency end of the spectrum are distinctly non- vertical[18]. From the figure 3 the spikes are obtained at an angle of less than 90_ to the real axis it is due to the roughness of the electrode/electrolyte interface[19]. The ionic conductivity is obtained from the relation $\sigma=L/R_{b*}A$ where L is the thickness of the sample, bulk resistance (Rb) and A is the area of the electrode, respectively. The bulk resistance (Rb) was found from the semicircle crossed the Z^l-axis, the diameter of the semi-circle at higher frequency decreases, implying that the bulk resistance (R_b) decreases. From the obtained values the ionic conductivity can be calculated. Bulk resistance of samples as a function of Graphite, A and WA concentration at room temperature (303 K) is found to be $8.5x10^6$ S/cm,$8.2x10^5$ S/cm,$9.9x10^2$ S/cm and ionic conductivity samples as a function of Graphite, A and WA is $4.21x10^{-7}$ S/cm,$7.76x10^{-6}$ S/cm,$1.58x10^{-4}$ S/cm from the obtained values it can be concluded that ionic conductivity is more found in processed ash on comparing the values of Ash and Graphite Pallet is as shown in table 1. This may be due to the increasing influence of the ion pairs, ion triplets, and the higher ion aggregations[20], which reduces the overall mobility and the number of effective charge carriers it is believed that the difference in the conductivity depends on the degree of the crystallinity and the flexibility of the polymeric backbone. Conductivity increase is directly proportional to flexibility of the polymeric backbone and inversely proportional to the crystallinity of material. It is due to the fact that path of the ion movement is blocked by the crystalline region and the amorphous region increases the flow of ions and facilitates the motion of ionic charge[21]. In our experiment we found that ash and processed ash showed good conductivity as increase in the concentration of salt. It is be due to the fact that salt decreased the degree of crystallinity and increased the presence of dominant amorphous region.This enhances the ion and polymer segmental mobility that will, in turn, enhance the ionic conductivity.

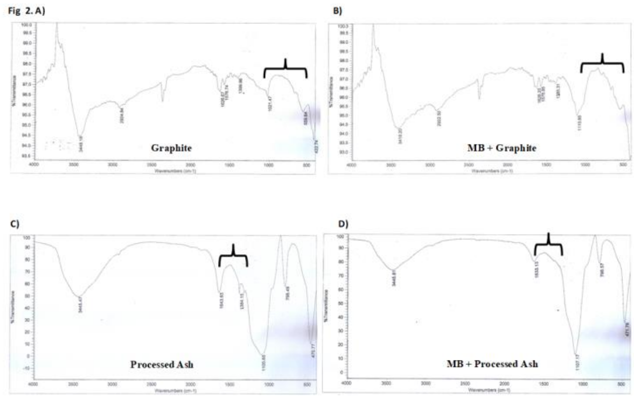

Figure 2.FT-IR analysis of (a) Graphite (b) Methylene blue + Graphite (c) Processed Ash (d) Methylene blue + Processed Ash. Closed brackets indicate change in the functional groups of graphite and ash respectively.

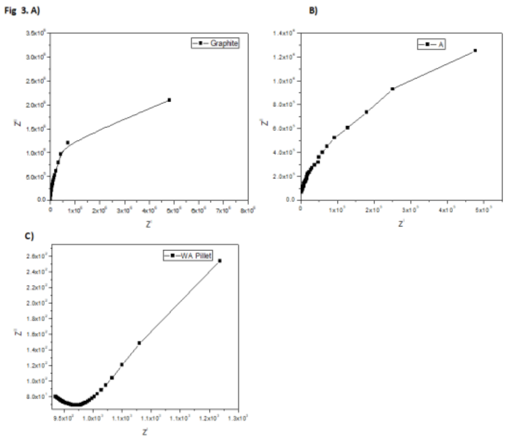

Figure 3. Complex impedance plots of (a) Methylene blue (b) Methylene blue + Graphite (c)Methylene blue + Ash (d)Methylene blue + Processed Ash.

Table 1. Ionic Conductivity values of Graphite, Ash and Processed Ash pallet

Ionic conductivity for Graphite	Ionic conductivity for Ash	Ionic conductivity for Processed Ash
Bulk resistance Rb for Graphite = 8.5x106 S/cm	Bulk resistance Rb for A= 8.2x105 S/cm	Bulk resistance Rb for W A= 9.9x102 S/cm
σ =L/Rb A For Graphite Pallet	σ =L/Rb A For A Pallet	σ =L/Rb A For WA Pallet
=4.21x10-7 S/cm	=7.76x10-6 S/cm	=1.58x10-4 S/cm

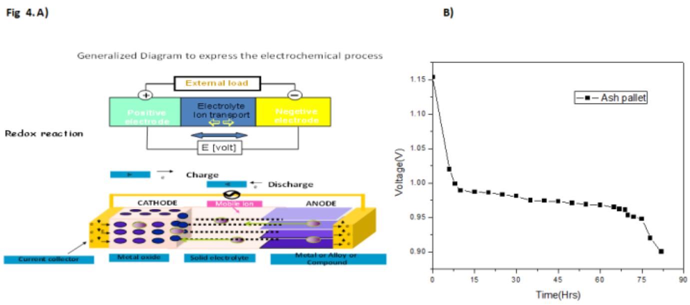

Figure 4. A) Generalized diagrams to express the electro chemical process. B) Voltage vs time plots of MB + Ash pellet.

Discharge characteristics. Solid state electrochemical cells were fabricated with the combination of Mg^+ (anode)/ Processed AshPallet/(I+C+electrolyte)/(cathode). Here the Magnesium metal is used as anode while, a mixture of I + C + electrolyte is used as a cathode as shown in Figure 4 The anode and cathode material was made in the form of a pallet. And the thickness of the pallets is nearly 1mm.the charge transfer takes place in anode material is due to magnesium while in cathode material graphite powder enhances its electronic conductivity[22]. The discharge characteristics were studied for a cell at a constant load of 100 kΩ at room temperature is shown in Figure 5. From Figure 5 there is an initial sharp decrease in the voltage for the entire cell it may be due to the polarization and formation of a thin layer of Magnesium salt at the electrode-electrolyte interface [23]. The discharge characteristics for the prepared Ash pallet were found to be at 80Hrs which can be used for electrochemical cell devices. The cell parameters of the present study are reported from the literature Mg^+-based [24], Ag^+-based [25]. Hence this cell shows better performance at room temperature. Similarly, other agricultural waste derived ash was used for developing low-dielectric glass-ceramics [26].

4. CONCLUSIONS

The Ash of Banana agricultural waste effectively decolorization of Methylene Blue dye was witnessed at 0.01gms of ash which is similar to 0.02gms of graphite in respect to decolorization of MB dye. This was confirmed by FT-IR analysis which may be due to ion exchange between dye and ash. This material displayed a good conductivity which is of the same level as commercial graphite. The maximum ionic conductivity was found to be $7.76x10^{-4}$ Scm^{-1} for the composition of processed ash. Finally, the electrochemical analysis revealed that the discharge characteristics for the prepared Ash pallet were found to be at 80Hrs which can be used for electrochemical cell devices.

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