Studies on Characterization of Solid Fuel using Municipal Solid Waste from Bida, Nigeria

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ABSTRACT

Municipal solid waste (MSW) in Bida, Nigeria consists of domestic waste with the addition of commercial waste. Disposal of this wastes constitute environmental problem in Bida and Nigeria in general. Selected amounts of MSW were considered in this study which are dried grass, melon peels, paper, sugarcane bagasse and saw dust. These materials were carbonized at 350^{o}C and the solid carbon fuel obtained were analyzed using particle size, x-ray diffraction (XRD) and scanning electron microscopy (SEM). The particle size measurement showed that dried grass has percentage intensity using dynamic light scattering at Z-average (135.2 nm), polydispersity index (0.453) and duration of 60 s. The mineralogical properties observed from XRD analysis showed that minerals like calcite, graphite, quartz, magnesium and gypsum were present. The peaks indicated at 2θ were within the range of 21^o - 58.5^o. Out of these, 21^o was for sugar cane bagasse in crystal area and 58.5^o for saw dust in amorphous area. The morphological properties revealed rough surface, hollow structure, homogeneous particle and irregularity. The particle size, mineralogical and morphological properties indicated that the solid carbon produced can be applied in direct carbon fuel cell, cement industry, iron and steel industry. The proper application of these solid carbon fuels can reduce environmental problems associated with MSW disposal in Nigeria.

Keywords: *Ultimate, Proximate, particle size, MSW, XRD and SEM*

1.0 INTRODUCTION

Municipal solid wastes (MSW) in Bida, Nigeria include largely house hold waste (domestic waste) with addition of commercial waste produced within the municipal. They are either in solid or semi-solid form and generally will not include industrial hazardous wastes (Usman, 2012). The primary source of MSW is the production of commodities and by products from solid materials. A secondary source of solid waste is the natural cycle of plant growth and decay, which is responsible for the portion of the waste stream referred to as vegetative waste. Newspapers are one of the largest contributors to MSW because they are used in large numbers, and they have a short useful life span. MSW is characterized by products that are large or small, and produced in large numbers possessing short useful lives and a great source of energy potential if properly channeled. The composition of MSW dumps varies widely, from developed countries to developing countries. MSW management is a crucial part of the economy of the world and when properly harnessed could help developing countries in power generation and other industrial applications (Adeniyi *et al.*, 2014; Poestotati and Mustiachi, 2012; Nabegu, 2010; Ryu, 2010;Vassilev *et al*., 2010; Sorum *et al*., 2001).

The population of Nigeria been on a steady increase and this is very true for most towns in the country, particularly of Bida. This population explosion is the direct result of "change in lifestyle", "technology, innovation, breakthrough" and "increased consumption" of goods in and out of the major cities (Johari *et al*., 2012). Urban cities in developing countries like Nigeria faces many challenges relating to solid waste management due to the high growth in their population, they are also constrained by lack of effective recycling of the biodegradable components to give useful resources, poor waste handling arrangement and ineffective waste management policies (Henry *et al*., 2006; Kuo *et al.*, 2008; Mor *et al*., 2006). The developing economies of the world require more electricity to be generated to the power grid. An alternative way of making use of the MSW is by utilizing the syn-gas and carbon fuel from municipal waste, in fuel cells to generate electricity. Direct carbon fuel cells (DCFC) and solid oxide fuel cells (SOFC) have the potential to provide higher energy efficiencies (up to 60% low heating value (LHV)) than conventional steam turbines or other types of internal combustion engines (Adeniyi *et al.*, 2014; Dikwal et al., 2009). Given the high amounts of waste generation in Bida and other cities in Nigeria, these fuel cell technologies would be good avenues for energy generation. This paper focuses on looking at the energy capacity of MSW in Bida Nigeria with a potential of generating power to augment the national grid as well as to look at other industrial application from MSW (Adeniyi *et al.*, 2014; Ewan and Adeniyi, 2013; Adeniyi and Ewan, 2012; Babayemi and Dauda, 2009; Dikwal et al., 2009; Klass, 1998).

2.0 METHODOLOGY

MSW materials were collected from different sites in Bida metropolis. These were sorted out and subjected to pyrolysis reaction at 350^{o}C. The carbon fuel produced were analyzed using proximate, ultimate, XRD and SEM.

2.1 SEM ANALYSIS PROCEDURE: Scanning Electron Microscopy (SEM) images were taken on a JEOOL-JSM 5600 LV microscope, equipped with a 6587EDS (Energy Dispersive X-ray spectrometry) detector, using an accelerating voltage of 15 kV. The sample were deposited on a sample holder with an adhesive carbon foil and sputtered with gold dust coating.

2.2 XRD ANALYSIS PROCEDURE: X-ray powder diffraction (XRD) was used for identification of unknown crystalline materials. The equipment is Eupyrean diffractometer DY 674 (2010) with a copper anode material. It works with a combination of other components like the water chiller which cools the X-ray tube and maintains a uniform temperature. There was also the compressed air that helps in opening and closing of the cabinet door. The goniometer was set up in vertical mode and configured for theta-theta and alpha-1 diffraction geometries. The goniometer was 240 mm. The diffractometer consist of three basic elements: x-ray tuber, a sample holder and an x-ray detector. Data collector was connected to the XRD machine with the Xpert Highscore plus which was used to analyze and interpret the data to produce the resulting diffractographs. The peaks obtained from the analyses were matched with the minerals from International Centre for Diffraction Data (ICDD) database which was attached to the software of the machine.

3.0 RESULTS AND DISCUSSION

The results of the XRD analysis of selected MSW are presented in Figures 1-3 while the SEM analysis presented in Figures 4-6.

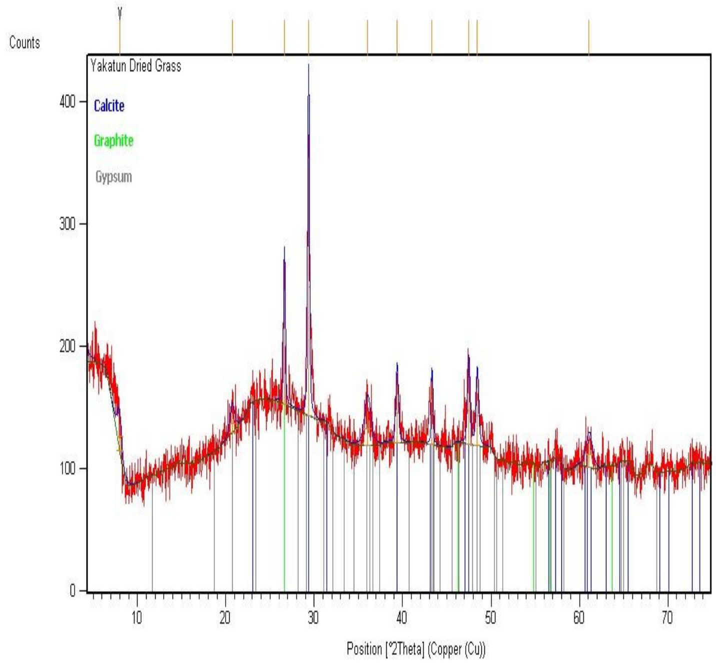

Figure 1: XRD pattern of dried grass- Matching compounds in selected MSW

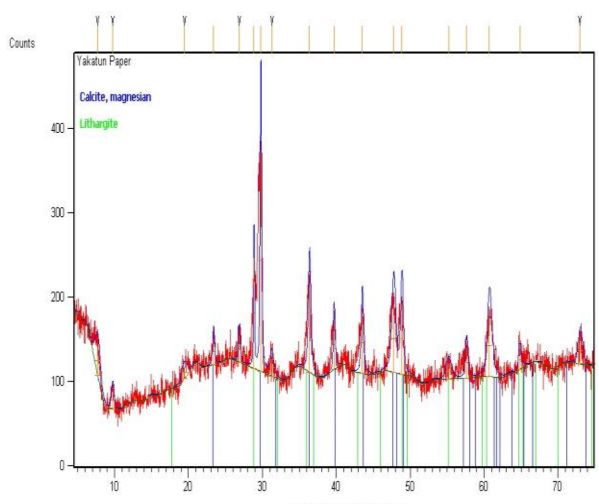

Figure 2: XRD pattern of paper- matching compounds in selected MSW

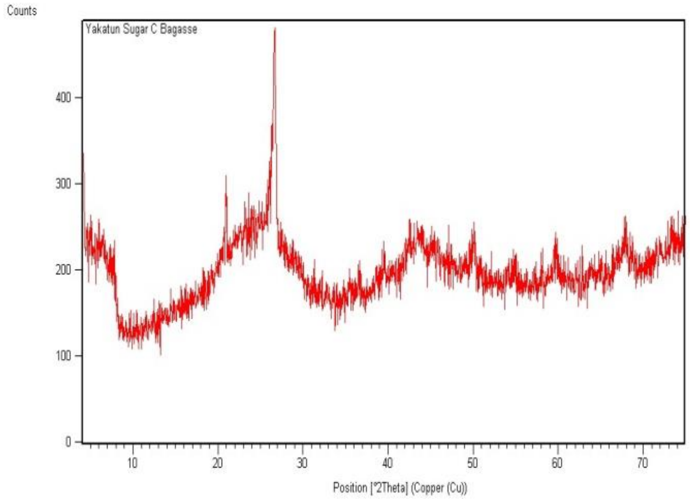

Figure 3: XRD pattern of sugar cane bagasse in selected MSW

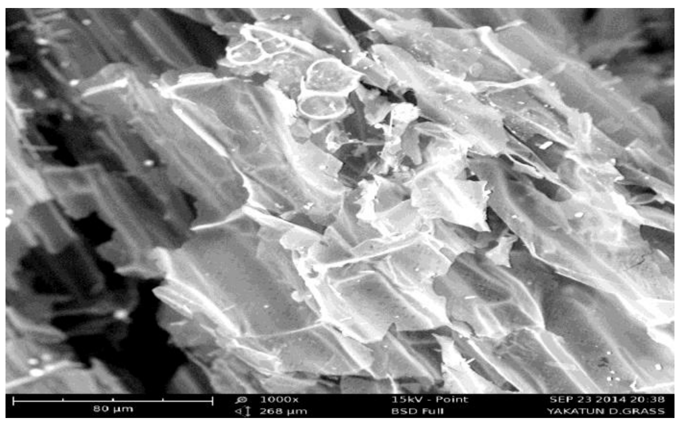

Figure 4: SEM analysis of carbonized dried grass.

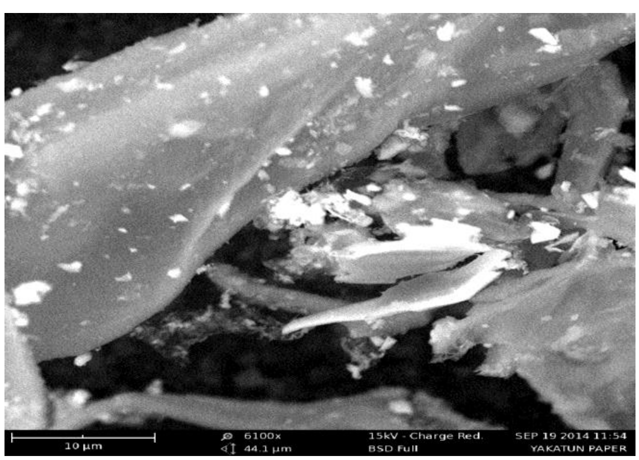

Figure 5: SEM image of the morphological analysis of carbonized paper

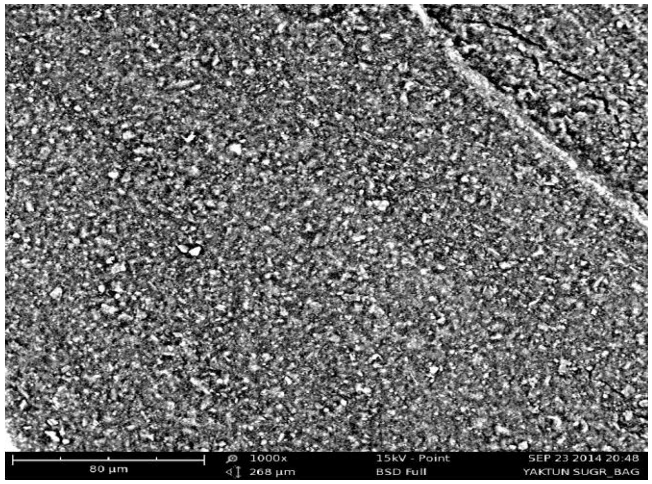

Figure 6: SEM image of the morphological analysis of carbonized sugarcane bagasse.

In the powder XRD graphs for the selected MSW (Figures 1,2 and 3), the compositions identified from dried grass are calcite ($CaCO_3$), graphite-3R (Rhombohedral), and gypsum ($CaSO_4.2H_2O$). The crystallographic parameter are crystal system calcite (Rhombohedral) with space group of R-3C and space group number of 167, graphite-3R with space group of R-3m and space group number of 166, gypsum (monoclinic) with space group of 12/a and space group number of 15. A well defined peaks at (2θ) value of 27^0, 29.5^0, 39^0, 43^0, 48^0 and 46.5^0. Out of these, 27^o, 29.5^o, 39^o are in crystal area. The solid carbon fuel has potential applications in the portland cement industry, iron and steel industry, direct carbon fuel cell (DCFC), sugar industry and in making crucible (Adeniyi *et.al*, 2014; Ewan and Adeniyi, 2013; Babayemi and Dauda, 2009).

From Figure 2, the power XRD graph from MSW paper, the minerals identified are calcite magnesium [$(Ca,Mg)CO_3$] and lithargite, syn (PbO). The crystal systems are calcite, magnesium (rhombohedral) with space group R-3C and space group number 167. Lithargite, syn (tetragonal) with space group of p4/nm and space group number 129. Well-defined peaks at (2θ) value of 29.5^o, 27^o, 37^o, 39.5^o, 49^o and 62^o. Out of these, 42.5^o, 46.5^o, 49^o and 62^o are in amorphous area and the others are in crystal area. The carbon has potential applications in making crucible, DCFC and lead glass, it could also be used as a drier in paints (Adeniyi *et.al*, 2014; Adeniyi and Ewan, 2012; Nabegu 2010).

The powder XRD graphs for the selected MSW of sugarcane bagasse is presented in Figure 3. The mineral identified is quartz (SiO_2). The crystallographic parameters are crystal system of quartz (hexagonal) with space group of P 3221 and space group number 154. Well defined reflections at (2θ) value of 21^o and 26.5^o. The two prominent peaks are in the crystal area. The carbon fuel has potential applications in similar industries.

Figure 4 shows the morphological structure of carbonized dried grass at 350^oC, with about 1000 times magnification. The result of this morphological structure showed a brittle and hollow structure cellulosic material which is characterized with roughness and appreciable porosity. These characteristics could be attributed to thermal stress induction in the material, during the carbonization to the high temperature of 350°C, thus potentially leading to the distortion and deformation as seen in the image. Figure 5, shows the morphological structure of carbonized paper. The SEM micrograph reveals long cellulosic strands of materials, interwoven with large cracks within the interstitials. The difference in the morphological structure of these materials, in comparison to the carbonized dried grass of image in Figure 4, could be attributed to the differences in experimental conditions and composition of feedstock (Ryu, 2010; Nabegu, 2010).

Figure 6 shows the morphological structure of carbonized sugarcane bagasse. The SEM micrograph of sugarcane bagasse reveals the presence of smaller particles that appeared to be well-bonded aggregates rather than detached particles with irregular and rough surface. The roughness could be attributed to improper accelerating voltage setting and too large magnification.

Tables 1 and 2 present the results of the ultimate and proximate analyses of the MSW. Table 1 shows percentage composition of selected MSW moisture content (%Mc) within the range of (5.4 – 26.6%). The high percentage composition of moisture content was in dried grass 8.76%. The sugar cane bagasse with low percentage moisture content 5.423 %. Table 1 also indicates the percentage composition of selected MSW volatile matter (%Vm). It refers to the part of MSW that was released when the MSW was burn at 750°C for 2 hours. The highest percentage composition was observed in sugar bagasse 76.923 % and lowest percentage in dried grass 61.956 %. The percentage of volatile matter influences the chemistry of solid fuels.

Table 1: Proximate analysis of MSW

S/No.	Sample	%Mc	%Vm	%Ac	%Fc
1	Dried grass	8.763	61.956	10.766	18.513
2	Waste paper	5.283	74.58	8.750	11.390
3	Sugarcane bagasse	5.423	76.923	13.776	3.876

Table 2: Ultimate analysis of MSW

S/No.	Sample	% C	% H	% N	% S	% O_2
1	Dried grass	44.843	3.686	2.113	1.066	48.290
2	Waste paper	43.000	4.740	8.750	0.993	47.980
3	Sugarcane bagasse	54.756	5.823	13.776	0.636	44.966

Table 1 also shows the percentage composition of Fixed Carbon (%Fc) of selected MSW. The carbon found in the material that was left after a volatile material was eliminated. The highest percentage Fixed Carbon was found in melon peels (21.390%) and dried grass (18.513%). The lowest percentage fixed carbon was recorded in saw dust (2.633%). The low percentage fixed carbon release low heat and prolong heating time. The higher the percentage fixed carbon content, the better the MSW charcoal produced because the corresponding energy content is usually high (Nabegu, 2010). From Table 1, the lowest percentage composition ash content (%Ac) was observed in melon peels 3.988% and saw dust 3.023% compared to sugar bagasse with the highest percentage composition ash content of 13.776%. The solid carbon fuel could be used for energy utilization in generating heating energy, electricity and other heating system (Adeniyi *et.al*, 2014; Ewan and Adeniyi, 2013; Adeniyi and Ewan, 2012; Nabegu 2010).

Table 2 shows the percentage elemental composition of carbon content present in selected carbonized MSW. The highest percentage was in sugarcane (54.756%) compare to waste paper (43.00%). The percentage of carbon (%C) content in the sugarcane is an indication of good higher energy content, because the amount of carbon content in the sample studied is an indication that they will contribute to the combustibility of the solid fuel. Table 2 shows the percentage composition of sulphur (%S) in selected MSW. The percentage sulphur content were low and for dried grass was above 1 % (Vassilev *et al*., 2010; Musa, 2007).

4.0 CONCLUSION

A characterization of the morphological, structural and material compositions of municipal solid waste in Bida metropolis of Nigeria has been conducted through XRD and SEM analysis. Results show that this municipal waste from Bida possesses good morphological characteristics which make it economically beneficial to Bida community- for instance, it can serve as excellent feedstock for power generation (when used as feedstock for DCFCs and SOFCs) – thus helping to augment Nigeria's power need and by extension it will also serve to alleviate the problems of municipal waste disposal. Furthermore, our investigations have shown that MSW materials have good potential application in cement, iron and steel as well as in fuel cells i.e. the direct carbon fuel cells and solid oxide fuel cells. There is a need to convert the wastes into industrially and domestically useful purposes most especially in the area of energy generation and also to prevent environmental degradation and pollution of the metropolis.

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