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Estimation of Energy Potential of Municipal Solid Wastes from Aba Dumpsites in Nigeria

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Abstract

Modified Dulong's model (MDM) was used to estimate the energy contents of municipal solid waste (MSW) from Aba dumpsites. American Society for Testing and Materials standard methods (ASTM) were used to determine percentage composition and ultimate analyses, thermal degradation and energy content the MSW. The results of % composition of the MSW showed that plastic (2.50 %) was the lowest while food waste (65.00 %) was the highest. The ultimate analysis results are carbon (44.50-62.50 %), hydrogen (4.30-8.50), oxygen (33.50-43.50 %), nitrogen (0.00-5.50 %), S (0.00-0.68 %) and Ash (2.5-8.00 %). The energy content of the MSW which was calculated using MDM found to be 20.53 mJ/kg. The result revealed that I kg of MSW from Aba dumpsites can produce about 21mJ/kg of energy. Therefore, conversion of MSW to energy can serve as profitable means of managing environmental pollution in developing nation and elsewhere in the world.

Keywords: Environmental pollution, Municipal solid waste, Energy, Calorific value, Dumpsite.

Introduction

Recently, many African cities have undergone unprecedented growth in population through migration from rural areas to urban centres which has resulted to the growth of cities into sprawling "mega-cities" with unplanned sub-standard housing and few services [1]. As a result of human population growth, changing lifestyles, technology development and increased consumption of goods, municipal solid waste generation has increased. This increase in wastes generation if not properly managed may lead to environmental problems.

Municipal solid wastes are wastes from various sources such as industrial, domestic, hospital and educational wastes and can be diverse in nature. The disposal of most waste in landfills should be done after proper waste management functions [2]. However, proper landfill practice is not prevalent in developing countries. This results in developing open dumps of different materials ranging from perishable food wastes to toxic, hazardous chemicals which pollute water, soil and air and cause poor aesthetic quality of the environment [3;4].

Developing nations are facing energy crisis which poses a challenge to their economic and social development despite having abundant solid wastes. Good waste energy recovery step from municipal solid waste can address the problems of solid waste management and partly the energy crisis. This method has advantageous in that it can lead to substantial reduction in volume and mass of solid wastes in our municipalities. In order to apply the method in a large scale, there are fundamental parameters such as fuel behaviour in thermal degradation, energy contents and its chemical reactions that should be in place so as to assist designers to come up with an appropriate method of waste energy recovery and disposal system.

The cornerstone of successful planning for a waste management program is the availability of reliable information about the quantity and the type of material being generated and an understanding about how much of that materials collected. Effective waste management through municipal solid waste (MSW) composition studies is important for numerous reasons. These include the need to estimate material recovery potential, to identify sources of component generation, to facilitate design of processing equipment, to estimate physical, chemical, and thermal properties of the waste and to maintain compliance with regulatory bodies [1].

This study is aimed at evaluating the compositions (physical and chemical) and energy potential in MSW from Aba landfills in South-eastern Nigeria as a case study in the study of wastes to energy conversion process.

Materials and Methods

Site Description

A wastes dumpsite in the commercial city of Aba located in South Eastern Nigeria was selected for the study (Figure 1). The city experiences two distinctive seasons in a year; dry season (from November to March) and rainy season (from April to October). Information from Nigerian National Population Commission showed that the city has human population of about four million (4,000,000).

As a commercial city, traders and markets (Ariaria international market, Shopping Centre etc.) are dominant in the town as a traditional lifestyle of the people. The town’s commercial nature contributes to the generation of different categories of solid wastes. However, all these wastes generated are normally dumped in landfill site at Umuigwe Osisima (Figure 1) which covers about 8 to 10 hectares. Aba city daily wastes generation capacity is about 120 tonnes according to Abia State Environmental Protection Agency (ASEPA) [5].

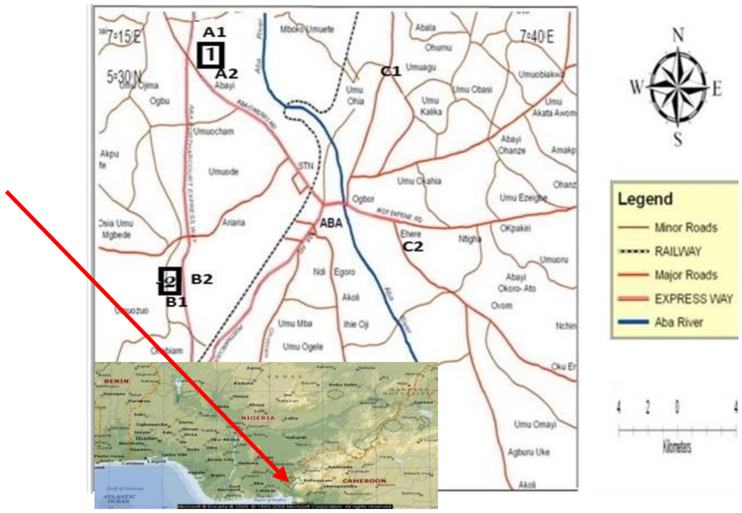

Figure 1: Map of Aba showing sample locations [6]

Methods

Sample collection and preparation

Solid wastes samples (10 kg) were randomly collected from dumpsites at Umuimo, Osisioma (Figure 1). The different categories of the wastes were weighed using weighing balance (Model: Mettler Toledo) after sorting and were separated according to defined classifications (glass, plastics, paper, metals and food waste). The combustible wastes were then preserved for analysis in accordance with ASTM [7] standard method of analysis while the non-combustible wastes were removed from the rest of the wastes.

Elemental analysis

The percentage composition of carbon, nitrogen, hydrogen, sulphur and oxygen contents of MSW were determined in this section. This was done using CHNS analyser (Model: Eltra 580, China).

Estimation of calorific value of MSW using Modified Dulong's formula

The amount of chemical energy in a given waste components (calorfic value)e was calculated using Modified Dulong's equation (equation 1). This depends on MSW's hydrogen, carbon, oxygen and nitrogen contents [8]

$$\text{LHV (kJ/kg)} = 337C + 1419(H - 0.125O_2) + 93S + 23N \qquad 1$$

Where LHV is low heating value, S = % sulphur content, C = % carbon content, O = % oxygen content, N = % nitrogen content, H = % hydrogen content.

Energy generation potential (EGP) of MSW

The energy recovery potential of the MSW was calculated using equation 2 [9].

$$\text{EGP (kW)} = \frac{W \times LHV \times 1000}{\eta_b \times 859.84} \qquad 2$$

LHV is the lower heating value (kcal/kg ɳ = the conversion efficiency ranges 22 – 28 %, W = daily waste disposal (tonnes), (IEA, 2007).

Figure 2: Thermo-gravimetric Analyser

Thermal degradation analysis

Thermal Gravimetric Analyser (Mettler Toledo TGA/DSC) was used to study the thermal degradation pattern of the MSW (Figure 2). MSW sample weight of 11.60 ±0.1 mg was used for the analysis.

Results and Discussion

Municipal solid waste composition

Table 1 and Figure 3 show the results of different categories of MSW from Aba dumpsite. According to Abia State Environmental Protection Agency, about 12 trucks deliver solid wastes to Osisioma landfill daily and each truck load of MSW weighs about 10 tonnes.

Table 1: Composition of MSW from Aba dumpsites

Categories of wastes	Weight (kg)	% Compositions
Paper	0.85	8.50
Food	6.50	65.00
Plastic	0.25	2.50
Wood	0.60	6.00
Textile	0.80	8.00
Others (non-combustible)	1.00	10.00
Total	10.00	100.00

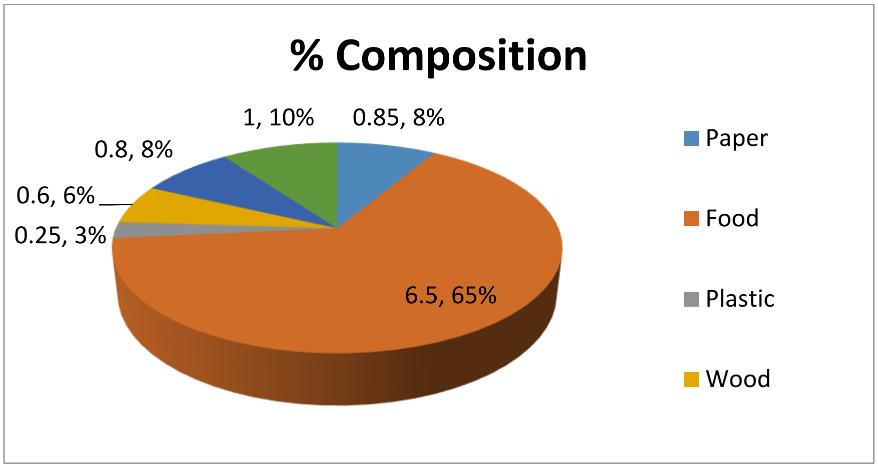

Figure 3: Percentage composition of municipal solid wastes from Aba dumpsites

The percentage composition of food waste (65 %) was the highest while that of plastic waste lowest (2.5 %). Other categories of MSW are paper (8.50 %), wood (6.00 %) and textile (8.00 %) non-combustible wastes (10 %). The results were in agreement with research result which found that food waste, was highest with percentage weight of 64 %. The MSW composition could vary from one place to another which largely depends on the level of citizen's income, social background, lifestyle, tradition and culture [8].

Results of ultimate analyses of MSW

The elemental analysis results and the calculated calorific values of MSW are as shown in Table 2 and figure 4. The results gave the % carbon, % moisture, % oxygen, % hydrogen, % ash, % sulphur, % nitrogen contents for different categories of MSW.

Table 2: Results of elemental analysis of MSW and their calorific values

Waste material	M.C (%)		C (%)	H (%)	O (%)	N (%)	S (%)	Ash (%)	Calorific value (KJ/kg)
	Wet	dry							
Food	72.46	11.70	47.50	7.50	37.50	1.96	0.68	4.86	4021.35
Paper	11.40	9.95	44.50	6.00	43.50	0.40	0.10	5.50	3162.64
Plastic	3.00	4.25	62.50	8.50	21.00	0.00	0.00	8.00	5879.83
Wood	18.26	10.00	50.00	6.30	40.50	0.50	0.20	2.50	3727.22
Textile	18.14	9.10	53.50	4.30	33.50	5.50	0.20	3.00	3666.85
%Composition	24.50	9.00	51.60	6.52	35.20	1.67	0.24	4.77	20457.88

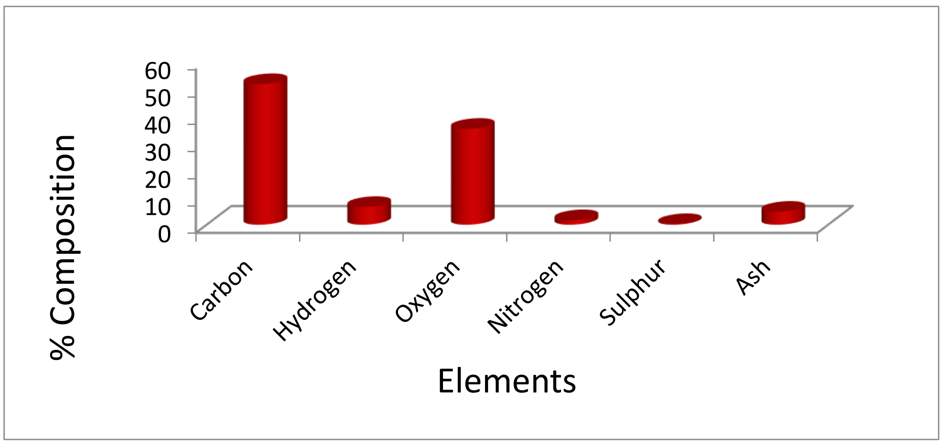

Figure 4: Percentage composition of elemental results of MSW from Aba dumpsite

The result of elemental analysis as shown in Table 2 and figure 4 revealed that paper wastes had lowest carbon contents (44.5 %) while plastic waste had the highest percentage composition of carbon (62.50 %). The results of hydrogen content of the MSW ranged from 4.30 % (textile to 8.5 % (plastic). The results of average % composition of hydrogen and carbon contents of MSW are more than 5 % and 50 % respectively, which contributed to increase calorific value of the MSW. The % composition of oxygen ranged from 43.50 % (paper) to 21.00 % (textile). The average % composition of oxygen was 35.20 % which was close to the result of [13] in which the % oxygen content was 34 %.

The ash content of the MSW ranged from 2.50 % (wood) to 8.00 % (plastic) which was relatively low but advantageous according to [14], for environment preservation and waste management due to possibility of having small quantity of organic pollutants, chlorine, heavy metals and salts. The results also show that the % composition of sulphur and nitrogen in the waste were 0.24 % and 1.67 % respectively. These values were low; therefore pollutants emissions released by these MSW during combustion will be very low. Development of proper MSW management method that can take care of environment and at the same time providing energy that will stimulate economic growth requires characterization of the wastes.

Calorific value of MSW.

The calorific value calculated using result of modified Dulong's formula as shown in Table 3 was 20.52 MJ/kg (4911.37 Kcal/kg). The results revealed that every kilogram of MSW from Aba dumpsites can produce about 20.52 MJ of energy. Plastic wastes gave the highest energy value (5879.83 kJ/kg) and the least came from paper (3162.64 kJ/kg). The result was similar research result by [15] which observed that energy from plastic in MSW was highest.

The calorific value of MSW (20.52 MJ/kg) was similar when compared to the energy value of MSW obtained in a research by [5], The high volume of solid waste generated in Aba metropolis can be put to beneficial use such as obtaining new products deriving cleaner form of energy through waste to energy conversion [16].

Energy Generation Potential (EGP)

The energy recovery potential of the MSW calculated with weight of MSW in tonnes and the calorific value (kcal/kg) of the MSW was 31.16 MW/h (Table 3). Though the heating value is low, nevertheless the utilization of solid waste in energy production is considered as good source of energy. This is because it also takes care of the environmental pollution. Therefore, there is advantage in using MSW as source of energy.

Table 3: Energy contents of MSW from Aba dumpsites

	Modified Dulong's model
Calorific value (MJ/kg)	20.52951
Calorific value (kcal/kg)	4911.37
EGP (MW)	31.56

Results of thermal degradation analysis of MSW from Aba dumpsite.

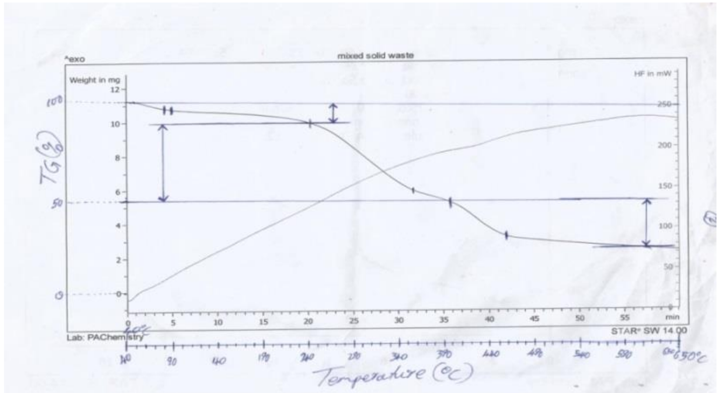

Figure 5: Thermo-gravimetric curve of MSW from Aba dumpsite

Thermal degradation analysis (TDA) of MSW

Figure 5 shows the TGA thermogram which has different stages representing loss of different materials at different temperature ranges. In the first Stage, moisture and other volatile materials were lost which occurred within the temperature range of 40 ^{0}C – 200 ^{0}C. The first peak appeared at very low temperature which may be due to high volatile materials such as methanol and ethanol which probably were derived from vegetables, fruits and foods wastes.

At the second stage (Figure 5), volatile matters were released which corresponds to pyrolysis of lignocellulose biomass. Hemicelluloses which are contained Lignocellulose biomass in Lignocellulose can decompose within the temperature range of 240 - 360 ^{0}C and lignins decompose at wider range 160 – 627 ^{0}C. These are believed to have come from yard trimmings, paper, food wastes etc.

Degradation of plastic and hemicellulose at the final stage (third stage). It temperature ranged from 280 – 640^{0}C and above. This came mainly from paper, wood, textile and plastic and covers about 30 % of the entire curve.

Conclusion

Uncontrolled and open solid waste dumpsites are common solid waste disposal method in Nigeria and developing nations. Low capital investment has led to these landfills being improperly designed thus allowing for environmental pollution in those areas where they are sited.

However, proper management of wastes such as reuse and recycling of solid waste in form of compost, biogas and energy recovery if properly harnessed can help to increase power generation, clean environment and will positively affect Nigerian economy and that of developing nations. The estimation of energy content of MSW from Aba dumpsite will draw the interest of government and non-governmental organizations in solid wastes to energy production.

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