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Determination of Physico-Chemical Characteristics and Energy Potential of Municipal Solid Wastes from ABA Dumpsites, ABIA State, Nigeria

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ABSTRACT
The determination of energy generation potential from municipal solid wastes as a profitable method of managing solid waste was studied. Percentage composition, proximate analysis and energy content of municipal solid waste (MSW) were determined following American Society for Testing and Materials standard methods. The results of % composition of the MSW showed that food waste (62.00 %) was the highest and plastic (3.5 %), the lowest. The proximate analysis results of the MSW were volatile matter (15.60-29.20 %), fixed carbon (56.85-70.90 %), moisture content (MC) (3.00-72.45 %) for wet sample, MC (4.3-11.70 %) for dry sample and Ash (2.85-4.85 %). The energy contents of the MSW were calculated using Bento's model which was based on the results of proximate analysis. The calorific value of the MSW was found to be 20.87 mJ/kg. This means that approximately 21 mJ/kg of energy can be produced by 1 kg of MSW from Aba dumpsites. Also the power generation potential of MSW was estimated to be 31MW. Therefore the study revealed that energy that can be produced from MSW from Aba Metropolis was higher than energy from other biomasses (17 mJ/kg) but lower than energy from coal (37-40 mJ/kg). Thus, waste to energy can be introduced as energy efficient and environmentally sound method of managing MSW in Aba metropolis and elsewhere in the country.

KEY WORDS: *Municipal solid waste, Dumpsite, Energy, calorific value and Pollution,*

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I. INTRODUCTION

The social and environmental impacts caused by municipal solid waste (MSW) have received attention in recent decades. Consequently, several policies, strategies, plans and methods have been developed in the field of MSW management. These include waste reduction and waste recovery for reuse, recycling, composting and incineration for energy generation in addition to land filling of final rejects, river dumping (Narayana, 2009).

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 (Edward, 2001). 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 and cause poor aesthetic quality of the environment (Cunningham *et al.*, 2005).

The existing dumping sites in Aba mostly are not properly engineered and managed; pollutants that are released or discharged from the disposal sites eventually caused direct and indirect impact to human life. As a consequence, the solid waste management system (SWMS) needs to be updated to suit the waste quality, quantity and composition. Incineration considered as option for waste reduction potential which can be 80-95% in terms of waste volume and only the final inert materials from incinerating being considered for land filling (Rand *et al.*, 2000). This method will reduce the quantity of incoming solid waste to landfills and also open opportunities for new technologies in treating MSW. The first step to understand the feasibility of design the incineration plan is to obtain the basic data regarding to quantity and quality of generated MSW in Aba.

Implementation of proper solid waste management programme has the potential to support the principles of sustainable development (Momoh *et al.*, 2010). Utilisation of biomass in conventional energy generation is obtaining a great deal of attention due to environmental considerations and the growing requirements for energy globally. The practise of reuse and recycling of solid waste in form of compost, biogas and energy recovery if properly utilized by the developing countries can help to increase power generation, alleviate poverty and reduce the problem of unemployment (World Bank, 1999; Cunningham and Saigo, 1999).

As at today, Nigeria is not self-sufficient in energy production and at the same time spends so much in tackling environmental pollution. Energy security in Nigeria and sub-Saharan Africa requires continuous research, diversification and development so as to increase our reserve growth. It is imperative to boost our nation's energy production and one way of achieving that is by exploration and production of energy non-conventional sources such as municipal solid waste.

This study aimed to determine characteristics and evaluate the potential of recoverable energyof wastes from Aba landfill site.

MATERIALS AND METHODS

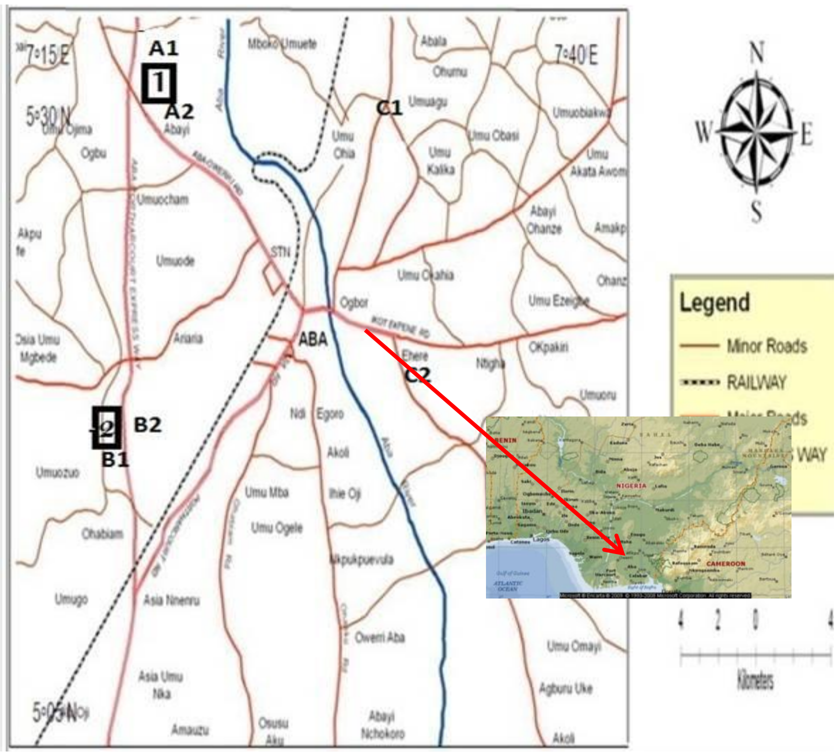

Figure 1: Map of Aba showing the sampled locations

Site Description

This study was carried out in waste dumpsite in Aba municipalities, the commercial city of Abia State. The town is located in the South Eastern region of Nigeria; the city has two climatic conditions in a year, the dry season and rainy season. The dry season starts from October to March while therainy season is from April to September annually although it varies due to seasonal changes. It has human population of about four million (4,000,000) (NPC, 2012). The residents are mainly traders, artisans and civil servant. The commercial nature of Aba leads to the generation of different forms of solid wastes from markets (e.g. Ariaria international market, Shopping Centre etc.), Abia State Polytechnic, Rhema University, School of Health Technology, Hospitals and other small companies. However, all these wastes generated are dumped in Umuigwe Osisima which covers about 7 to 9 hectares. According to Abia State Environmental Protection Agency (ASEPA), up to 120 tonnes of wastes are generated in Aba daily.

Materials used

Figure 2: Oven (Model: UNB 500) Figure 3: Furnace (model: Carbolite-T0115982)

Proximate analysis

Proximate analysis consists of moisture content, ash content, volatile matter and fixed carbon. This was done by putting the selected solid waste sample to different range of the temperature programmes (between 100 °C to 950 °C). The laboratory methods for measuring the proximate analysis of solid waste samples in this research was carried out based on American Society for Testing and Materials (ASTM) standard (ASTM, 1998).The procedures for all the analysis were replicated three times and the average values were taken.

Moisture Content

The percentage moisture contents of the MSW fresh samples were determined by weighing 500 g of the samples into a pre weighed drying pan and dried the samples in an oven (Model: UNB 500) at 105°C to a constant weight (figure 2). The percentage moisture content (MC) was then calculated as a percentage loss in weight before and after drying (equation 1) (ASTM 3173).

% Moisture content = 1

Volatile Matter Content

The volatile matter content was determined by the method of ignition of the sample at 950 °C. The triplicate samples of MSW material used in the moisture content determination was weighed and placed in a furnace (model: Carbolite-T0115982 (Figure 3)) for 7 minutes at 950°C (ASTM D3175). After combustion, the sample was reweighed to determine the ash dry weight, with volatile solids being the difference between the dried solids and the ash (equation 2).

VS (%) = 2

Where VS is volatile solid

Fixed Carbon Content

Ash content of waste is the non-combustible residue left after waste is burnt, which is represented in natural substances after carbon, oxygen, sulphur and water. This was analysed by drying the samples at 750°C for 1 hour in a furnace (model: Carbolite-T0115982) (figure 3). Fixed carbon is defined as carbon found in the material which was left after volatile test. Fixed carbon was determined by removing the mass of volatile from the original mass of the sample (equation 3).

FC (Wt% wet basis) = 3

Where Wt is weight, FC is fixed carbon, MC is moisture content and VM is volatile matter.

Ash = ash (wt %), VM = volatile matter (wt %).

Determination of calorific value of MSW

The calorific value is the amount of chemical energy in a given waste components which depends on its carbon, moisture and hydrogen contents. The calorific value of the sample was calculated using Bento's model. Bento's model uses the results of proximate analysis of the MSW and was created based on the percentage of volatile matter and moisture content of the sample. It gives accurate estimation of calorific value and has advantage in that; it gives result that is based on sample size (Ogwueleka and Ogwueleka, 2010)**.**

Bento's model
LHV (kcal/kg) = 44.75VM – 5.85MC + 21.2 - 4
Where LHV is lower heating value (kcal/kg)
VM is volatile matter (%), MC is moisture content (%) (JNMSWF, 1991).

Energy Generation Potential of MSW
Energy recovery potential of the MSW was calculated using equation 5 (Sudhir et al. 2010).
Energy generation potential (kW) = 5
Where LHV is lower heating value (kcal/kg)
W = daily waste disposal (tonnes)
ɳ = the conversion efficiency which ranges between 22 – 28 % (IEA, 2007)

II. RESULTS AND DISCUSSION

Composition of MSW from Aba dumpsites

The results of compositions of different components of the municipal solid wastes are presented in Table 1 and figure 4. A truck load of MSW in Aba contains about 10 tonnes of MSW and average of 12 trucks deliver solid wastes to Osisioma dumpsite according to information from Abia State Environmental Protection Agency. Therefore Aba generates about 120 tonnes of solid wastes daily.

Table 1: Percentage composition of MSW from Aba dumpsites

Type of waste	Weight (kg)	% Composition
Food	6.20	62.00
Paper	0.95	9.50
Plastic	0.35	3.50
Textile	0.70	7.00
Wood	0.50	5.00
Others (non-combustible)	1.30	13.00
Total	10.00	100.00

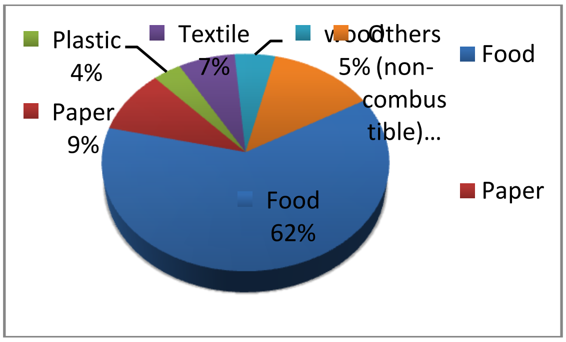

Figure 4: Percentage Composition of municipal solid wastes from Aba dumpsites

The results revealed that food waste is the highest, with percentage composition of 62.00 % followed by other non-combustible wastes (13 %). Others combustible wastes are paper (9.50 %), textile (7.00 %), plastic (4 %) and wood (5.00 %), (figure 4). In the results of Alaa et al. (2012), food waste was found to be the highest with percentage weight of 64 %. MSW composition could vary from place to place according to income level, lifestyle, social background, culture and tradition (Wang and Nie, 2001).

Proximate of MSW

The results of proximate analysis of MSW from Aba dumpsites are presented in Table 2 and figure 5. The results showed the percentage of the moisture content, volatile matter, ash content and fixed carbon in combustible forms of MSW.

Table 2
Proximate analysis of MSW from Aba dumpsite

waste	MC (%)		VM (%)	Ash (%)	FC (%)
	Wet	Dry			
Food	72.46	11.70	18.70	4.85	64.75

Paper	11.40	9.95	17.45	4.60	68.00
Plastic	3.00	4.30	36.00	2.85	56.85
Textile	18.26	10.00	15.60	3.50	70.90
wood	18.14	9.10	29.20	3.50	58.20
Total	123.26	45.05	116.95	19.30	318.70

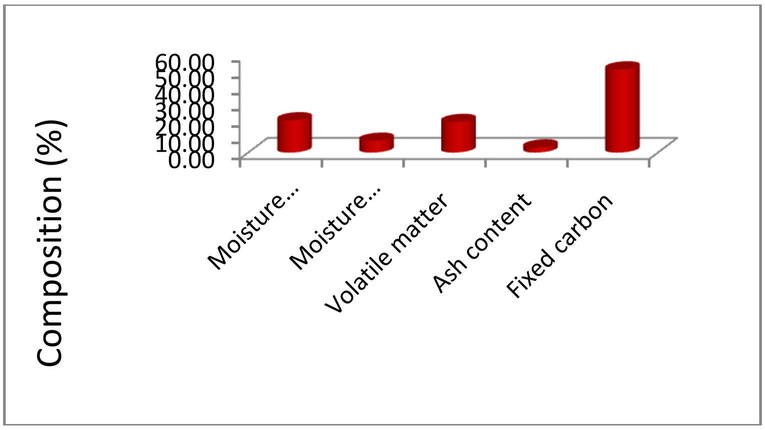

Figure 5: Results of proximate analysis of MSW from Aba dumpsites

Results of proximate analysis of MSW from Aba dumpsite

The results of proximate analysis of MSW as presented in Table 3 and figure 5 revealed that the moisture content of the MSW ranged from 3 % in plastic to 72.46 % in food waste for the wet sample. Also in the dry samples, food waste with 11.70 % has the highest moisture while plastic waste (4.30 %) has the lowest moisture content. The result is similar to the research result of Amin and Yang (2011) where the moisture content of food waste was the highest among other waste categories.

The results of the volatile matter (VM) of the MSW as shown in Table 3 and figure 5 indicated that plastic has the highest % of volatile matter (36.00 %), followed by wood (29.20 %), food (18.70 %), paper (17.45 %) and textile (15.60 %). Volatile matter of MSW is vapour released when waste is heated in a covered crucible in a furnace to a temperature of 950 ^{0}C for two hours. The result of % volatile matter content of the waste is similar to the results obtained by Omari (2015) in which the volatile matter ranges from 30.02 to 34.69 %. High volatile matter content is useful in energy content determination. MSW sample with high volatile matter and low moisture content usually gives high calorific value.

Among all the parameters analysed for in the dry MSW sample, fixed carbon is highest which ranged from 56.85 % in plastic to 70.90 % in textile (Table 3). Other results of the FC include 68.00 % in paper, 58.20 % in wood and 64.75 % in food. Generally, the volatile matter and fixed carbon contents are highest as shown in Table 3 and figure 5 in dry sample. The high fixed carbon of MSW will need to be burned on a grate as it takes a long time to burn out, unless it is pulverized to a very small side (Inesa et al, 2012).

Table 3

Calorific values of MSW calculated from proximate results using Bento's model

Waste	MC (%)		VM (%)	Ash (%)	FC (%)	LHV-(Bento model) (kcal/kg)
	Wet (%)	Dry (%)				
Food	72.46	11.7	18.70	4.85	64.75	790.165
Paper	11.40	9.95	17.45	4.60	68.00	744.38
Plastic	3.00	4.30	36.00	2.85	56.85	1607.26
Textile	18.26	10.00	15.60	3.50	70.9	661.30
Wood	18.14	9.10	29.20	3.50	58.20	1275.12
Total	123.26	45.05	116.95	19.30	318.70	4993.42

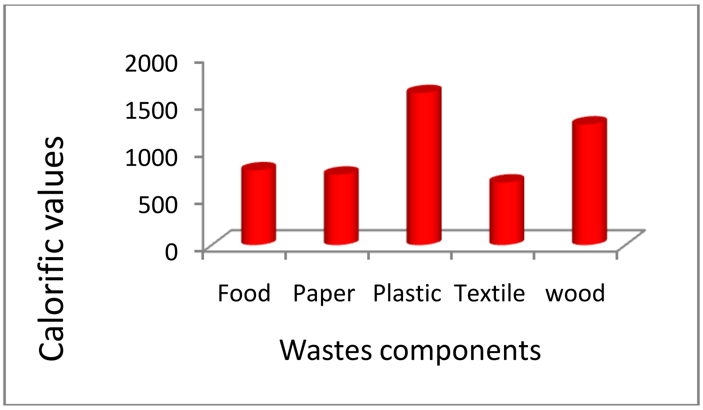

Figure 6: Calorific values for different components of MSW using Bento's model

Results from determination of energy potential of MSW
The results of energy potential determination of MSW are presented in Table 7. The results show the calorific values and Energy generation potential of MSW calculated using Bento's formula.

Table 4: Calorific value and energy generation potential of MSW dumpsites

Energy contents	
Calorific value (MJ/kg)	20.8725
Calorific value (kcal/kg)	4949.06
EGP (MW)	31.66

Calorific value of MSW
The calorific value obtained using Bento's model was 20.87 MJ/kg (4993.42 Kcal/kg) is shown in Table 4. The result is higher than the energy contained in other biomasses which is about 17.00 MJ/kg but lower than energy contained in coal (37 – 40 MJ/kg) (Surroop and Juggurnuth, 2011). This means that energy produced by one kilogram of coal will be produced by about two kilograms of MSW.

The calorific value of MSW (20.87 MJ/kg) from Aba dumpsites is also higher than the value obtained by research results from Kenya according to Sorum and Hustad, (2001) who estimated the calorific value for MSW in Nairobi, Kenya 12.48 MJ/kg. It was observed that the moisture contents of the waste played a crucial role in reducing the energy value, however due to the high volatile matter content of the waste; the energy was also relatively high.

Energy generation potential (EGP)
The result of energy generation potential of the MSW from Aba as shown in Table 4 was 31.66 MW/h. Energy recovery potential of the MSW was calculated using the calorific value (kcal/kg) of the MSW and weight of MSW in tonnes. The heating value of MSW is low and therefore the power production per unit mass of the MSW is also low. Nevertheless, the waste utilization as source of renewable energy is considered as good source of energy because it generates energy and at the same time takes care of the environmental pollution. Therefore, there is advantage in using MSW as source of energy.

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