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Characterization and Generation of Municipal Solid Waste in North Central Nigeria

[1]M. B. Oumarou, [2]M. Dauda, A. T. Abdulrahim[1], [3]A. B. Abubakar
[1.] *Mechanical Engineering Department, University of Maiduguri, Borno State, Nigeria.*
[2]. *National Agency for Science and Engineering Infrastructure (NASENI), Abuja, Nigeria*
[3]. *Department of Mechanical Engineering, Ramat Polytechnic, PMB: 1070, Maiduguri; Borno State, Nigeria*

Abstract: *The study focused on the characterization and generation of municipal solid waste in the north central part of Nigeria. Daily samples were collected and interpreted using Microsoft Excel for quantification purposes while the characterization samples were collected during the months of February, March and April and during the raining season in August. The refuse physical characteristics were then evaluated by sifting through the waste and separate it into its various physical major components. They were analyzed for proximate and ultimate composition using ASTM standards. Average moisture contents were found to vary from 26.743 to 32.593. Wood, paper, plastic and leaves were found in varying proportions and an average waste generation of 1. 23 kg per person per day was found. Energy recovery is possible with an addition of supplementary fuel as sugar cane straw, weeds. The knowledge of the refuse CV alone is not enough to conclude whether the refuse will burn or not. Its moisture content is also an essential parameter.*

Keywords: *municipal solid waste, generation, characterization, north central Nigeria, ultimate analysis, proximate analysis, calorific value, semi-arid region.*

I. INTRODUCTION

In developing countries where waste management systems are insufficient and inefficient, coupled with the expanding urban population [1, 2], the problem of refuse disposal is reaching proportions that are causes for concern. Also, the operation and management of municipal solid waste (MSW) collection services are fairly rudimentary. This is reflected in the lack of information about the quantities and types of MSW collected, the amounts recovered, recycled and/or reused and the sitting of MSW disposal sites [3].

Semi-arid regions of the world are defined as the transition zones between arid and sub humid belts and precipitation is less than potential evaporation, characterized by high temperatures (30^{o}C- 45^{o}C) in the hottest months [4]. In Africa, these regions are mainly characterized by low annual rainfall and the whole area is mainly desertique. Added to this, is the almost inexistent and erratic power supply from the national grid. Wastes are an important source of energy presently used in the generation of electricity and at the same time making the environment clean. The National energy supplies are at present almost entirely dependent on fossil fuels and firewood which are depleting fast [5].

Diso *et al.* [6] characterized the refuse in Kano and found that 13 megawatts of electricity could be produced from wastes in 1995 covering at least the entire Kano metropolitan area. Mengiseny and Josia [7] are of the opinion too that the main problem facing policy makers in the waste management sector is how to predict the amount of solid wastes generated in the near future in order to devise the appropriate treatment or disposal mechanism. Agunwamba *et al.* 8] analyzed the waste in Onitsha (Nigeria). Also in the southern part of the country, Adeyemi et al.[9] investigated the impact of waste scavenger in case study of Ilorin. Jekayinfa and Omisakin [10] considered ten agricultural wastes in Nigeria to determine their energy content using the method of Association of official Analytical Chemists. Results of their analysis showed that the mean higher heating values of the wastes samples were 16505kJ/kg, 19597kJ/kg, 20647kJ/kg, 15891kJ/kg, 17303kJ/kg, 19458kJ/kg, 28203kJ/kg, 19299kJ/kg, 21392kkJ/kg and 21143kJ/kg for groundnut shell, yam peels, coconut shell, mango peels, palm oil mill effluent, corn cob, cherry, orange peels, melon shell and black walnut hull respectively. All the waste samples considered have heat values greater than some well-known biomass-fuels and fall within the limit for the production of steam in electricity generation.

Paolo [11] investigated the effect of separate collection of municipal solid waste on the calorific value of the residual waste. He emphasised that separate collection plays an irreplaceable role in solid waste management and incineration. Considering the average Italian municipal solid waste composition, he proposed separate collection scenarios different from those tested; he proposed a regression model, calibrated it and teste it partially.

Ogaji *et al.* [12] investigated the municipal solid waste (MSW) generated in Port Harcourt. They found it in large quantities, but some remains as litter in parts of the municipality. Refuse is mostly buried, but some reckless open-burning ensues, so posing environmental hazards.

Due to the heterogeneous nature of MSW, it is very difficult if not almost impossible to make projections. A comprehensive characterization of municipal solid waste is crucial to the long-term efficient and economical planning for solid waste management. Often, the problem is more pronounced when the choice of the best treatment option, to dispose of the MSW, is at hand. This paper focuses on the generation and characterisation of MSW in the north central semiarid region of Nigeria within the 2006-2011 period, for the purpose of choosing the best and appropriate option to treat and dispose of these wastes. The determination of the wastes combustion characteristics and evaluation of the amount of energy to be obtained from such wastes is carried out.

II. MATERIALS AND METHODS

Study area:

Major cities of the north central of Nigeria, with high population densities [13] and intense industrial activities constitute the area of study. These cities are: Kano, Katsina and Dutse in Kano State, Katsina State and Jigawa state respectively.

Data collection:

Daily data on the waste load weights collected by the trucks of the municipalities were used. To this were added the door-to door and dump -to- dump data collected, because not all parts have access to collection by trucks. Other information was provided by the various States Environmental Protection agencies of the study area. The entire population of the study area selected cities was considered in order to obtain a per capita estimate, according to the National Bureau of Statistics data of 2006. For characterization purposes, the samples were collected during the months of February, March and April and during the raining season in the month of August. The refuse characteristics were then evaluated by sifting through the waste and separate it into its various physical major components.

It should be noted that all samples taken at the various refuse dumping sites contain a large proportion of sand which had to be removed prior to any measurement. This is due to the fact that sand is an inert element in the combustion process. Furthermore, a first sieving is carried out followed by hand picking, carried out to remove small stones which could not pass through the sieve. The sample were then sieved again using a 2 mm mesh sieve, before being ground to powder form using a small porcelain mortar and pestle. Generation rates of MSW were obtained using Equation (1) [3].

$$PCG = \left[\frac{\left(\frac{Waste\ \ generated}{Weeks}\right)\left(\frac{Weeks}{Days}\right)}{Population}\right] \text{(Kg/ day. person)} \qquad (1)$$

where PCG is the per capita waste generation

Materials:

A digital METTLER TOLEDO AB 54 weighting machine with limitations of 10 mg minimum and a maximum of 51 grams. Glass ware equipment include 16 pieces of PYREX conical flasks, pipettes, burettes, beaker, volumetric flask, plastic bottles and filter papers; a digital Spectrometer SPECTRUMLAB 22 PC as well as a Gerhardt - Kjeldatherm machine.

The reagents are: Sulphuric acid (H_2SO_4), Orthophosphoric acid (H_3PO_4), Ferrous sulphate ($FeSO_4$), Sodium Fluoride (NaF), Potassium dichromate ($K_2Cr_2O_7$), Diphenylamine indicator, Kjeldhal tabs, Boric acid, Absolute ethanol, Bromolysol green methyl red, Sodium hydroxide. Nitric acid, acetic acid, magnesium sulphate, gum Arabic, barium chloride. Others are Potassium chloride (KCl), Sodium hydroxide (NaOH), Hydrochloric acid (HCl) and Phenolphthalein indicator.

Analytical techniques

Proximate analysis:

This is performed by weighting, heating and burning a small sample of waste to determine the moisture content (M'_o, in weight percent (w/o)) by driving off the free moisture at ~ 107^o C for approximately 1 hour [14] as shown by equation (2).

$$C'_{f(w/o)} = 100 - \left[M'_{(w/o)} + V'_{(w/o)} + A'_{s(w/o)}\right] \qquad (2)$$

Ultimate analysis:

It is a quantitative evaluation of the total carbon (C'), hydrogen (H'), nitrogen (N'), sulphur (S'), oxygen (O') percentages after removal of the moisture and ash [15,16]. This analysis is performed using classic oxidation, decomposition, and/or reduction technique to determine, C (carbon), H (hydrogen), N (nitrogen) and S (sulphur). Oxygen O' (w/o) is calculated by difference using the equation as shown below [14]:

$$O'_{(w/o)} = 100 - \left[C'_{(w/o)} + H'_{(w/o)} + N'_{(w/o)} + S'_{(w/o)} + M'_{o(w/o)} + A'_{s(w/o)}\right] \qquad (3)$$

Heating value or calorific value:

The ash free, dry heating value can be calculated to 2% accuracy by using the Dulong- Berthelot formula [17]:

$$Q'_d = 81.37C' + 345\left[H' - \frac{(O' + N' - 1)}{8}\right] + 22.2S \qquad (4)$$

All data interpretation, calculations and graphs were carried out and generated using Microsoft Excel, 2007.

III. RESULTS AND DISCUSSION

MSW physical characteristics, generation rates as well as the proximate and ultimate analyses results in each of the towns with higher population density are shown in Figure 1, Table 1 and Tables (2 and 3) respectively.

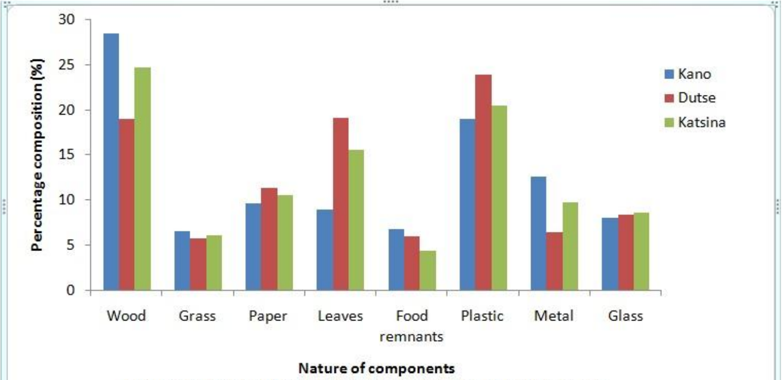

Figure 1: Physical composition of MSW in the study area

Table 1: Average MSW generation in north central Nigeria

Locality	Generation (kg/person/day)		
	Low	Medium	High
Kano	1.43	1.6	1.8
Dutse	0.68	1.0	1.22
Katsina	1.0	1.12	1.25

Table 2: Proximate analysis of waste samples in north central Nigeria.

Locality	Elements (%)			
	Moisture (w/o)	Volatile matter (w/o)	Ash (w/o)	Fixed Carbon (w/o)
Kano	32.593	25.256	32.150	10.000
Dutse	29.655	20.460	33.260	16.622
Katsina	26.743	23.406	34.750	15.100

Table 3: Ultimate analysis of waste samples in north central Nigeria

Locality	Elements (%)				
	C (w/o)*	H (w/o)	N (w/o)	S (w/o)	O (w/o)
Kano	21.470	0.460	0.685	0.560	12.080
Dutse	21.000	0.120	1.382	0.088	14.495
Katsina	20.965	0.340	1.050	0.291	15.861

* weight percent

The calorific value of refuse (fuel) is the property of fundamental importance. It is a complex function of the elemental composition of the refuse or waste.

Table 4: Calorific value (CV) of waste in the study area

Locality	Calorific value (MJ/kg)
Kano	5.667
Katsina	5.345
Dutse	5.379

The generation and composition of household waste are not homogeneous. They vary according to changes in commercial activities, population behavior, consumption patterns and economic growth rates and depend upon the season of the year, day of the week. Generation rates were found to vary between 0.68 kg and 1.8 kg per person per day. The study are average MSW generation was found to be 1.23 kg per person per day against 1.2 kg per person per day in the north eastern Nigeria [18].

The variation in the CVs of refuse (Table (4)) was due to differences in the gradation of the constituent materials. The refuse CV in Kano with a higher population density approaches the one in Katsina which has a relatively lower population density. The differences in CVs are not significant even though their population densities are not the same. However, these wastes can immensely impact water quality and sanitation if left untreated.

The present finding is in agreement with Ogaji et al. [12] who found that waste collected from different receptacles and dumpsites in the city of Port Harcourt consisted of 66.6% volatile solids, 13.5% fixed solids, 19.1% liquid and 0.8% other components. They also found an average biodegradability fraction is 0.807, with a carbon-to-nitrogen ratio of 27:1. The energy content of the refuse was 7.25 MJ/kg as collected. Their results indicated that such refuse is amenable to several disposal options with less adverse impact on the environment.

It is well-known that MSW can be used to generate electricity. Research published since the 1970’s has reported the use of the biodegradable component in MSW to generate biogas, which can also be used to generate electricity and has positive environmental implications, such as the reduction of greenhouse gas emissions from sanitary landfills and the replacement of highly polluting energy sources (oil, coal and natural gas) [3]. In all the cases, energy recovery is possible with an addition of supplementary fuel since the values in the study area fall below the 7.50 MJ/kg to 12.00 MJ/kg (an acceptable recommended range suggested by Whiting [19]).

Population density and geographic locations are not real determining factors as whether refuse quality may change or not but rather the life style of the population and their level of awareness towards waste management techniques. However, these factors do influence the generation rate of MSW. Options available for supplementary fuels include: Water hyacinth, sugar cane in the Kura, Bunkure, Hadejia areas.

IV. CONCLUSION

Physical characterization showed that wood, grass, metal, plastic and paper were the constituents of all waste samples in the study area, but in varying proportions. Proximate and ultimate analyses of refuse in the area of study showed refuse characteristics as: Moisture: Volatile matter: Fixed carbon: Ash content, as 32.593: 25.256: 10.00: 32.150 for Kano.

Average daily municipal solid waste generation was found to be about 1.23 kg per person per day, and it is greatly influenced by population density and commercial activities.

Population density and geographic locations are not real determining factors as whether refuse quality may change or not but rather the life style of the population and the level of awareness of the population towards waste management.

The CVs were low but energy production is possible with the addition of a supplementary fuel such as bagasse, weeds or water hyacinth.

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