Characteristics and Composition Analysis of Municipal Solid Waste in Port Harcourt City, Nigeria – A Prelude to Methane Emission Estimation in the City's Dump Sites

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Abstract— The composition of solid waste in three dump sites (Eliozu, Igwuruta, and Iwofe) in Port Harcourt city have been analyzed and characterized using Physical and Proximate analysis. Physical characterization of the solid waste at the three dumpsites showed that plastics have the highest percentage composition (28.34%-26.80) followed by food waste (27.40%-25.60), Textiles (12.10% to 10.30%), Paper (12.00%-11.60%), Rubber (8.50-7.20), Tin cans (8.10% - 6.70%), Ferrous metal (0.91-0.50), miscellaneous organic (0.80% - 36%), metal (0.70% - 0.40%), non-ferrous metal (90.40% - 20%). Proximate analysis was conducted and the results obtained showed that the solid waste at Eliozu dumpsite has the highest moisture content of 55.75% while the waste at Iwofe dumpsite has the lowest moisture content (45.28%). The volatile matter content ranges from 55.12% to 51.91% with solid waste at Iwofe dumpsite having the highest and Igwuruta dumpsite having the lowest. The Ash content ranges from 48.86% - 40.74% with Igwuruta having the highest and Iwofe the lowest. Also solid waste from Iwofe dumpsite has the highest fixed carbon with Eliozu dumpsite having the least. The waste streams in Port Harcourt city have been shown in the present study to be heterogeneous in generation and characteristics for the three dumpsites.

Index Terms—Calorific Value, Composition analysis, Proximate Analysis, Solid Waste, Moisture Content.

1 Introduction

The Resource Conservation and Recovery Act (RCRA) [1] defines the term "solid waste as any solid, semi-solid, liquid or contained gaseous materials discarded from industrial, commercial, mining or agricultural operations and from community activities. Solid waste also includes food waste, construction debris, commercial refuse, sludge from water supply, water treatment plants, or air pollution control facilities, and other discarded material". Takele [2], in a lecture note developed in 2004 defined the term solid waste in a general term as encompassing the heterogeneous mass of items and materials thrown away from communities, towns, and cities as well as the more homogenous accumulation of industrial, agricultural and mineral wastes. Again, the Organization for Economic Cooperation and Development (OECD) [3] states that municipal solid waste is household waste and includes waste from commerce and trade, office buildings. It also defines it as waste from institutions, small businesses, yards and gardens, street sweepings, contents of litter containers and market cleansing. The list excludes waste from municipal sewage network and treatment, as well as municipal construction and demolition.
Industrial and domestic solid waste are produced due to industrial and domestic activities and in the last two decades, management of industrial and domestic solid waste which can also be referred to as municipal solid waste in this context has become a major concern due to considerable increase in its production in both absolute and per capita value.

Studies have shown that the challenge of managing waste is not limited to solid waste alone as there has been increase in waste chemical discharge that affect the soil at the discharge point, [18]. These waste also include waste from wood in the saw mill commonly referred to as sawdust, [6]. The amount of industrial and domestic (municipal) solid waste produced increases with economic growth This situation calls for an efficient solution [11]. A constant change in life style driven by advertisement and commercial interest also fosters the common trend of a life of waste – throwing away what could be reused. Worse of all the increase in waste generated in the form of waste packages and garbage result to road blockage, streams being filled up, water drainage systems made ineffective and clean air made toxic and poisonous by man with waste packages and garbage. This is common in developing economies which the region under study falls into. The amount of solid waste produced in the industry increases with industrial growth and this demand for immediate and efficient solution to save man and his environment. Technology has been hailed the saviour of mankind and vastly has become his executioner. Campaigns upon campaigns has come and gone yet the heap of the refuse in our societies seems to be

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leaping higher. Production cannot be stopped in the bid to curb refuse waste and its pollution trends. On the other hand, resources being the stuff with technology is built; it was grabbed by the industries as an unlimited-supply raw materials and by virtue of this they became nation pace setters [8]. Some of the solid wastes generated undergo recycling. This means getting something back from waste, example newspaper recovering for de-inking followed by repulsing to make more new print. Polyethylene terephthalate (PET) bottles have also been reused for various purposes in the local communities in the study region and beyond. Other wastes have also been recycled as a means of waste management. Generally speaking, the goals of industrial and municipal waste management have been identified by Chandrappa and Das [22] to include the promotion of the quality of urban environment, engage the teeming youths through employment generation and associated income, and the support for an efficient and productive. The aim of this study is preliminary data collection of solid waste discharged from industrial areas in Port Harcourt and the evaluation of the characteristics and composition analysis of the waste in order to obtain information about the quantity of recovery solid waste and its impact to our environment. Also, it is the aim of this research to sensitize all concerned people that according to World Bank records waste generation around the world in on the increase. As at 2012, the World Bank [14], reported that about 1.3 billion tonnes of solid waste are generated around the world per year in different cities. This situation amounted to a footprint of 1.2 kilograms per person per day. The situation will only get worse with an estimated rise to 2.2 billion tonnes of waste by 2025. Hence, another main principal objective of this study is to increase the sensitization for appropriate and more suitable collection, transportation and final disposal strategies for solid waste.

2.0 WASTE MANAGEMENT

Takele [2] defined solid waste management as the discipline associated with the control of generation, storage, collection, transfer and transport, processing and disposal of solid wastes in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, and that is also responsive to the public attitudes. The nature and operation of solid waste management varies significantly from nation to nation. Distinctions such as these are not limited to the national scale. However, and can be seen at the city and neigbourhood level. Regardless of scale, these differences are to some extent attributable to prevailing socio economic, financial, legal and political variables at that level. He further integrated sustainable solid waste management and that sustainability in this aspect or perspective implies looking at the whole waste management system, including waste prevention and recovery and searching for a system that best suits the society, economy and environment in question.[9], [13].

2.1 METHODS OF SOLID WASTE MANAGEMENT

Methods use in solid waste management is basically classified into three sub classes [12].

1. **Re-use**: This is typified by the returnable bottle. It makes several trips from the bottling company to the consumer and back again, where it is cleaned and refilled. Re-use may be allocated the highest availability in the recycling spectrum with respect to a developing nation.
   This is due to the fact that the last energy and process complexity is normally expanded in getting the material or article back to use. This is not the case with developed economies like the United States of Americ where there is efficient recycling that saves resources. According to EPA [15], recycling also prevents the release of approximately 186 million metric tons of carbon dioxide equivalent into the air in 2013—equivalent to taking over 39 million cars off the road for a year. Materials like sawdust have been recycled for use in pellets for energy generation and in composite for boards etc [6], [23]. This development gives impetus as to why recycling should be encouraged.
2. **Direct re-cycling**: Using the returnable bottle as our link example, once it is unfit for re-use due to chipped mouth or edge or broken. It may be crushed down for cullet (glass which is remelted at the glass work and used to make more bottles). This process depends on the quality of the recycled material and on it cost, which should exceed that of the virgin raw material. Direct recycling has an international availability in that both energy expenditure and process complexity may be required in getting the material back to use.
3. **Indirect recycling**: The indirect recycling often makes no pretence at reclaiming the material for is quite probably that at a certain stage its re-use or direct recycling becomes impossible due to quality. It will then eventually end up in the domestic dumps. However, it can still be extracted from the refuse by screening and separation in conjunction with other bottles. These other bottles will probably be of different quality and color and are unsuitable for cullet use.

3.0 MATERIALS AND METHOD

3.1 MATERIALS

The materials to be used for this experiment are: industrial solid waste, clamp, volumetric flask, retort stand, delivery tube, Rubber bucket, furnace and oven.

3.2 STUDY AREA

The study area is Port Harcourt, located in Rivers State, Nigeria. Rivers State has a population of 5,185,400, making it the sixth-most populous state in the country [20]. Port Harcourt is

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located on latitue 4°46'38.71" N and longitude 7°00'48.24" E based on Degrees Minutes Seconds (DMS) Coordinate [21]. Also, Port Harcourt is the state capital and a local government of its own with a population of 1,148,665 [21]. The dump sites under review spread across three Local Government Areas – Port Harcourt, Ikwerre and Obio/Akpor Local Government Areas as seen in Figure 1.

3.3 SOURCE OF SAMPLE

The Solid waste was sourced from three industrial dump sites in Port Harcourt city and nearby towns, then the clamp, volumetric flask, retort stand, delivery tube, and rubber bucket were sourced from mile 3 market in Diobu Area of Port Harcourt city, Rivers State Nigeria.

Figure 1: Map of Rivers State

Other materials were sourced from the department of chemical/petrochemical engineering laboratory, Rivers State University (RSU), where this experiments were performed.

3.4 METHOD

3.4.1 Proximate Analysis

The waste was analyzed using proximate analysis method in accordance with ASTM 3173-3175 standard methods. This standard stipulate procedure for determination of moisture content, volatile matter, ash content and fixed carbon of the solid waste samples from the three dumpsites. 2kg of samples of solid waste were collected from each dumpsite and taken to the Laboratory of the department of Chemical / Petrochemical Engineering, Rivers State University for analysis.

3.4.1.1 Moisture Content

Using ASTM 3173 as did Lawal [11] the moisture contents of the collected solid waste samples were calculated. 1kg of the sample was weighed and oven dried to constant weight at 105^{o}C. The moisture content was calculated as a percentage using equation (1):

Wet-weight moisture content is expressed as follows

$$M = \frac{w-d}{w} \; x \; 100 \; \% \qquad (1)$$

Where M = Wet-weight moisture content expressed as %; w = Initial mass of sample as delivered (kg); d = Mass of sample after drying (kg).

3.4.1.2 Volatile Matter Content

To determine the volatile matter content, the procedure in line with ASTM 3175 [16] was followed. 5g of the dried waste samples were weighed and placed in a muffle furnace. It was then heated for 7 minutes at 950^{0}C. The sample was heated to complete combustion and weighed to determine the ash dry weight. The volatile matter was calculated using equation (2) [11].

$$\% \, volatile\ Matter(V) = \left[\frac{(Dry\ sample\ weight\ -\ Ash\ weight)}{Dry\ sample\ weight} \right] x \ 100\% \qquad (2)$$

3.4.1.3 Ash and Fixed Carbon Content

Again following the procedure stipulated in ASTM 3174 standard, the Ash content of the sample waste were determined by heating the samples at 760^{0}C in an oven until complete combustion. The residue left after combustion represents the ash content of the sample and the Fixed carbon was calculated using equation (3).

$$\text{Fixed carbon (\% weight)} = 100\% - \text{weight (\% M + \% Ash + \% V)} \qquad (3)$$

All symbols retain their previous meaning.

3.5 CALORIFIC VALUE

The caloric value otherwise known as Lower Heat Value (LHV) of the Solid waste was determined using mathematical model developed based on the proximate analysis. To develop the model consideration was given to the weight percentage of volatile matter and fixed carbon. Amin *et al* [17] reported that using proximate analysis data is advantageous since the result generated are based on sample sizes and the models do give an accurate estimation of the calorific values [11]. Equation 3.5 is a model that is based on proximate analysis used for predicting the calorific value of MSW.

$$LHV = 45V - 6W \qquad (4)$$

where LHV: Lower Calorific Value (kcal/kg)
V: combustible volatile matter (%),
W: moisture content (%)

4.0 RESULTS AND DISCUSSIONS

Available data shows that 25662.13 tonnes of waste were collected for the month of March 2014, [19], while Table 1 gives the total waste disposed at the three dump sites in 2015.

Table 1: Average Monthly Tonnes of Waste Disposal in the Year 2015.

Dumpsites	Average Waste Disposal (Tones)

	Weekly	Monthly
Eliozu	1667.55	6670.28
Iguruta	4778.75	19115.10
Iwofe	2612.77	10451.08

Source: Rivers State Waste Management Agency, [19]

Solid wastes collected at different collection spots within Port Harcourt are transported to the dumpsite by trucks. Table 1 shows the average monthly and weekly disposals of solid wastes from the three major dumpsites in Port Harcourt city. The highest disposal rate of 4778.75 tones/week was recorded at Igwuruta dumpsite while Eliozu dumpsite had the least with 1667.55 tones/week.

4.1 PHYSICALCOMPOSITION / CHARACTERIZATION

The result of the characterization of the industrial solid waste at the three dumpsites conducted in the months of April, May (2015) are shown in Table 2.

Table 2: Average % Composite (weight)

Category	Eliozu	Igwuruta	Iwofe
Plastics	27.20	26.80	28.34
Food waste	24.40	25.60	23.40
Textiles	10.30	11.80	12.10
Paper	12.00	10.50	11.60
Rubber	8.50	7.80	7.20
Glass	6.60	6.90	5.70
Leather	1.10	1.40	1.50
Metal	0.65	0.40	0.70
Tin cans	7.60	6.70	8.10
Non Ferrous metal	0.20	0.40	0.30
Ferrous metal	0.91	0.60	0.50
Miscellaneous organic	0.50	0.80	0.36
	99.96kg	99.7kg	99.8kg

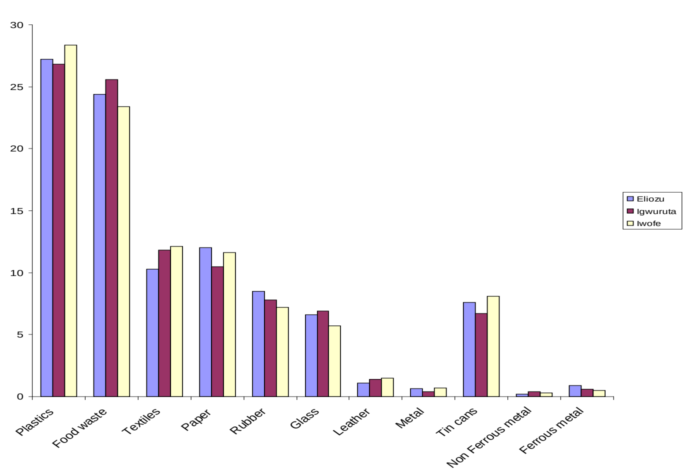

Fig. 1 Average percentage of solid waste composition at Eliozu, Igwuruta and Iwofe dumpsites.

Following a physical characterization of the solid waste at the three dumpsites, it was deduced that that plastics have the highest percentage composition (28.34%-26.80) followed by food waste with the composition (27.40%-25.60). Textiles waste has percentage composition ranging from 12.10% to 10.30%, paper 912.00%-11.60%), Rubber (8.50-7.20), tin cans (8.10% - 6.70%). Glass leather (6.90% - 5.70%),(1.50% - 1.10%), Ferrous metal (0.91-0.50), miscellaneous organic (0.80% - 36%), metal (0.70% - 0.40%), non ferrous metal 90.40% - 20%).

4.2 PROXIMATE ANALYSIS

Proximate analysis was conducted to determine the volatile matter, ash content, fixed carbon content and moisture content of the industrial solid waste from the three dumpsites. The analysis was conducted for the solid waste collected in the months of April, May (2015). The average result of the proximate analysis is shown in Table 3.

Table 3: Average moisture, Volatile Matter, Ash and Carbon Contents of solid waste from the dumpsite.

	PROXIMATE ANALYSIS		
Items (%weight)	**Eliozu**	**Igwuruta**	**Iwofe**
Moisture	55.75	48.76	45.28
Volatile matter	54.69	51.91	55.12
Ash	42.62	48.86	40.74
Fixed carbon	3.97	4.62	4.73

The result shows that the solid waste at Eliozu dumpsite has the highest moisture content of 55.75% while the waste at Iwofe dumpsite has the lowest moisture content (45.28%). The volatile matter content ranges from 55.12% to 51.91% with solid waste at Iwofe dumpsite having the highest and Igwuruta dumpsite having the lowest. The Ash content ranges from 48.86% - 40.74% with Igwuruta having the highest and Iwofe the lowest. Also solid waste from Iwofe dumpsite has the highest fixed carbon with Eliozu dumpsite having the least.

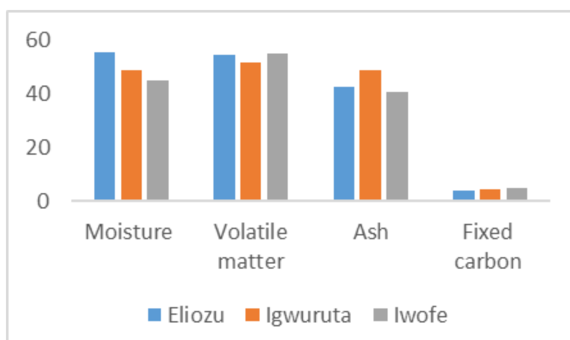

Fig 2: Average moisture, volatile matter, ash and fixed carbon contents of solid waste at Eliozu, Igwuruta and Iwofe dumpsites.

4.4 CALORIFIC VALUE

The lower caloric value or lower heat value (LHV) of the industrial solid waste was determined using mathematical model based on the proximate analysis. Table 4 waste at the three dumpsites

Table 4: Lower heat values (LHV) of Industrial solid waste at the three dumpsites.

DUMPSITES	LOWER HEAT VALUES (LHV)	
	Kca/kg	Mj/kg
Eliozu	2156.67	9.024
Igwuruta	2043.39	8.550
Iwofe	2208.72	9.242

The heat value of the industrial solid waste in the three dumpsites ranges from 9.242 MJ/kg – 8.550mj/kg with industrial solid waste from Iwofe having the highest LHV (9.242) Mj/kg while Igwuruta dumpsite have the lowest.

5.0 CONCLUSION

In this research work, Solid waste composition, characteristics, and effects were studied. The result show that solid waste discharged in Port Harcourt and its environ has plastic as its major component. This reality lays bare the need for efforts towards design and fabrication of recycling units that can convert the waste to cash while optimizing the operating condition of such equipment to withstand the Niger delta condition of the prevalence of black soot and humidity. The result also shows that it is important to evaluate alternative equipment needs, systems, management programs and plans especially with respect to the implementation of disposal, resource and energy recovery options especially in this era of global warming and the need to curtail it by controlling human activities on earth. The waste streams in Port Harcourt city have been shown in the present study to be heterogeneous, different in generation roles and characteristics for the three dumpsites. Again, the result from the analysis on the nature and amount of waste generated in the region obviously confirms the assertions of Cointreau in 1982 and Blight and Mbande in 1996 [4], [7]. The authors asserted that certain differences are observed between the wastes composition of Municipal Solid Wastes in developing economies and developed economics. Differences such as in waste density, moisture content, organic waste content and larger proportions of smaller content of components.[5]

This means that for a sustainable solid waste management in Port Harcourt and related regions of developing nations the strategy should be peculiar and suited for the location. This opinion is shared by Igoni, Abowei, Ayotamuno and Eze [10].

As a prelude to methane emission estimation this study indicates that there is likely hood of high methane emission considering the fact that food waste is between 24.40% to 25.60% of the total waste.

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