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Research Article

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Characterization and Experimentation of Municipal Waste for Electric Energy Estimation in Auchi Metropolis Nigeria

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Abstract Municipal solid waste management and low electric energy supplied are two major problems affecting the development of Auchi metropolis, Nigeria. This work aimed at determination of heat energy from municipal solid waste in Auchi, Nigeria and its potential for electricity generation. Hence, the municipal waste streams was characterized to determine the heating value of the various municipal waste components with Dulong"s formula.

Random truck sampling was used according to American Society for Testing and Materials (ASTM) in the collection of waste to the disposal site and characterized into six (6) parameters; food waste, plastic waste, paper waste, textile waste, garden trimming waste, and wood waste. 2 grams sample of the various municipal waste component were prepared for laboratory experimentation to determine their various chemical composition for the estimation of heat energy.

These resulted to an average heating value of 23,600.05kJ/kg on food waste, 21,572.755kJ/kg on plastics waste, 19,230.02kJ/kg on paper waste, 23,636.54kJ/kg on garden trimming waste, 22,364.72kJ/kg on textile waste, and 35,420.28kJ/kg on wood waste having total heat energy of 145,831.49kJ/kg in Auchi metropolis. The results showed that wood waste have the highest heating value for energy estimation in the metropolis. The study characterized waste and established the heating values for energy potential from the municipal waste components in the area. The results of this study showed that waste to energy solves the problem of municipal solid waste disposal while recovering heat energy from the municipal solid waste constituents boost electricity in Auchi metropolis, Nigeria.

Keywords Municipal Solid waste, Characterization, Experimentation, and Heat energy

1. Introduction

Waste and its production are an inevitable result of human existence. Waste generated in our households, schools, hospitals and businesses is called municipal solid waste. Municipal solid waste consists of everyday items that we use and throw away. Discarded products such as packaging, old furniture, clothes, leftover food, newspapers, batteries and more make up municipal solid waste. It is very closely linked to people, because people′s behavior determines when a certain item becomes a waste. Therefore, municipal solid waste reflects the culture of the people who produce it and has an impact on people′s health and the environment around them.

Municipal solid waste deserves special attention because of its impact on the environment at local, regional and global levels (Vergara, and Tchobanoglous, 2019). Municipal solid waste management is one of the major environmental problems of Nigeria cities including Auchi metropolis. Improper management of municipal solid waste causes hazards to inhabitants. Massive volume of solid waste is generated every day in the municipal areas and unfortunately solid waste management is deteriorating day by day (Shubham and Pradeep, 2017).

Haile *et al.* (2019) state that rapid urbanization, industrialization and population growth have led to severe waste management problems in several cities in Nigeria, and the uncontrolled urbanization has left many Nigerian cities devoid of many infrastructural services such as water supply, sewerage and municipal solid waste management. Most of the urban centers in Nigeria are overwhelmed by severe problems related to solid waste due to lack of low efforts by town/city authorities, garbage and its management. Great increase in the amount of municipal solid waste has been reported in the cities due to an improved lifestyle and social status (Egwurube *et al*. 2018).

Due to human activities in Auchi metropolis, municipal solid waste (MSW) is produced which may have resulted in various environmental problems. Although landfilling method has capability to control the wastes, there are several disadvantages such as hazardous gas emissions and leachate production arisen from landfilled wastes (Aliu and Ogbeide, 2021). They states that the existing dumping sites in Auchi are not properly engineered and managed; pollutant that are released or discharged from the disposal sites eventually caused direct and indirect impact to human's life such as;

i. Blockage of Drainage System
ii. Incubation of Diseases Pathogens
iii. Breeding of Diseases Vectors and Vermin
iv. Contamination of Drinking Water
v. Atmospheric Contamination

Aliu and Ogbeidde, (2021) states that Auchi metropolis has serious problem on municipal waste management and electricity, load shedding is now impractical as living standards now become a great barrier in socio-economic growth in the metropolis. Hence there is need for an alternative source of energy to boost electric energy supply in Auchi metropolis. Recovering energy from municipal solid waste is feasible by means of a number of energy generation processes such as combustion, pyrolysis and gasification. The aim of this work is to determine the heating values from municipal waste stream as a potential for electricity generation in Auchi metropolis, Nigeria.

2. Methodology

2.1. Research Design

In pursuance of these research objectives with a view to achieving the aim, adequate literature survey was conducted to gain insight into the waste management system in the metropolis. To this end, various areas of waste generation and disposal function were examined. From the examined area, suitable places were adapted to suit the purpose of the research work. With the in-site inspection the metropolis were divided into five (5) zones and (100) waste collection points in the metropolis in which relevant data were achieved from different waste components generated in Auchi metropolis as presented in Table 1.

Table 1: Solid Waste Collection Points in each Zone

Zones	Number of Collection Points
1	26
2	20
3	14
4	18
5	22
Total	100

**Source: Field survey, 2020

Method of Data Collection

Random truck sampling was used according to American Society for Testing and Materials (ASTM**)** (Lawal Abdu Daura, et al. 2018) in the collection of waste to the disposal site in the metropolis under study.

The municipal wastes were hand sorted for characterization to which the Net weight of the waste components from the five zones in the metropolis was statistically determined.

2.3 Method of Data Analysis

Samples of the generated waste component were taken to the Chemistry Laboratory, Federal University of Technology, Akure, Ondo State, Nigeria for Laboratory experimentation to determine the ultimate analysis of the various waste components.

Experimentation

Ultimate Analysis: this is an elemental quantitative evaluation of the total carbon (C), hydrogen (H), nitrogen (N), sulphur (S), oxygen (O), and percentages after removal of the moisture and Ash. This analysis was performed using classic oxidation, decomposition, and reduction technique to determine, carbon (C) content, hydrogen (H) content, nitrogen (N) content, and sulphur (S) content, and oxygen (O) was determined by difference. The experimental values of the ultimate analysis of the various municipal waste compositions are presented in Table 2.

Determination of Carbon and Hydrogen: 2g of sample was weighed into platinum crucible and placed in a Leibig – Pregle chamber containing magnesium percolate and sodium hydroxide. The sample was burnt off to produce Carbon (IV) Oxide and water. The CO_2 was absorbed by sodium hydroxide while water was absorbed by magnesium percolate. The amount of water and carbon dioxide were determined by difference using equation 1 and 2.

$$\%C = \frac{a\ X\ 0.2727}{Wt\ of\ sample}\ X\ \frac{100}{1} \qquad (1)$$

$$\%H = \frac{b\ X\ 0.1117}{Wt\ of\ sample}\ X\ \frac{100}{1} \qquad (2)$$

Where a = quantity of CO_2 recorded

b = quantity of H_2O recorded

Ash Content: The ash content was determined by weighing 2g of sample into a pre tarred and weighed crucible. This was heated in a muffle furnace at a temperature of 550^{0}C for four (4) hours. The residue obtained was used to determine the ash content using equation 3.

$$\%ASH\ (AC) = \frac{weight\ of\ residue}{Weight\ of\ sample}\ X\ \frac{100}{1} \qquad (3)$$

Determination of Nitrogen: Samples were analyzed chemically according to the official methods of analysis described by the Association of official Analytical Chemist (A.O.A.C., 18th EDITION, 2005). This consists of three techniques of analysis namely Digestion, Distillation and Titration.

Determination of Sulphur: 1g of sample was weighed into a 100 volumetric flask; 40ml of distilled water was added to make a solution of the sample. The mixture was properly homogenized to ensure complete dissolution of the sample. The above was filtered through a Whatman No. 1 filter paper into another 100ml volumetric flask. 5ml of the filtrates was pipetted into a beaker; add 2ml of 5% Na_2CO_3, followed by the addition of 1ml of 10% HCl solution. The mixture was stirred and filter through a Whatman No.42 filter paper into a 100ml Beaker, followed by dropwise addition of 10% $BaCl_2$, solution from a Burette with constant stirring and boiling on a water bath for 2hrs. The hot mixture was carefully filtered through Whatman No. 42 filter paper into another 100ml beaker, 1ml of 0.1M $AgNo_3$, added to produce a slight opalescence which confirms the presence of Barium Sulphate precipitate. The mixture was later filtered into a 250ml beaker with the precipitate as residue on the filter paper using equation 4.

$$\%Sulphur = \frac{\text{weight of filter paper plus residue – weight of empty filter paper}}{Weight\ of\ sample}\ X\ \frac{100}{1} \qquad (4)$$

The Oxygen content (% O) was obtained by difference using equation 5.

$$\%\ O = 100 - \%\ (C + S + N + H + AC) \qquad (5)$$

To determine heat energy for electricity from the municipal waste generated in Auchi metropolis, Dulong's model was applied as presented in Equation 6, (Shubham, and Pradeep, 2017)

$$\text{Heat Energy}\,\frac{\text{kJ}}{\text{kg}} = 337\text{C} + 1428\,(\text{H} - \frac{O}{8}) + 9s \quad (6)$$

Where C = carbon percentage

H = hydrogen percentage

O = oxygen percentage

S = sulfur percentage

3. Results and Discussion

Samples of (2) grams of the municipal waste generated in Auchi metropolis were collected for Laboratory experiment to determine the amount of carbon, hydrogen, oxygen, nitrogen, sulfur, and ash content for each type of municipal waste in the metropolis. These analyses were carried out in the Department of Chemistry, Federal University of Technology, Akure, Ondo State, Nigeria, and the results are presented in Table 2. The Dulong's model in equation 8 was applied to determine the ultimate analyses results for Heat Energy.

Table 2: Ultimate Analysis for Chemical composition of the various waste components

Components	%C	%N	%S	%H	%ASH	%O	Total
Food waste	49.22	3.577	0.464	5.265	5.233	36.241	100
Plastic waste	49.75	0.205	0.186	4.263	25.03	20.566	100
Paper waste	44.07	0.327	0.211	6.196	8.965	40.231	100
Garden Trimming	48.85	1.891	0.371	6.394	4.821	37.673	100
Textile waste	51.68	0.305	0.228	6.337	2.061	39.389	100
Wood waste	69.83	0.075	0.084	9.89	1.55	18.571	100
Total	**313.4**	**6.38**	**1.544**	**38.345**	**47.66**	**192.671**	

Source Chemistry Lab. (FUTA) Nigeria, 2022

To determine heat energy generated by whole Auchi metropolis solid waste, Dulong's model needs to be applied.

Dulong's model as described in Equation 8

$$\text{Heat Energy (kJ/kj} = 337\,C + 1428\,(H - \frac{O}{8} + 9S)$$

Where C = carbon percent

H = hydrogen percent

O = oxygen percent

S = sulfur percent

Putting percent by mass value from Table 2, into Dulog's model, Heat Energy generated from various municipal wastes in Auchi metropolis is determined as follows;

$$\text{Food waste (kJ/kg)} = (337 + 49.22) + 1428\,(5.265 - \frac{36.241}{8} + 9\,X\,0.464)$$

Heat Energy = 16,587.14 + 7,012.908 = 23,600.048kJ/kg

$$\text{Plastics waste (kJ/kg)} = (337 + 49.75) + 1428\,(4.263 - \frac{20.566}{8} + 9\,X\,0.186)$$

Heat Energy = 16,765.75 + 4,807.005 = 21,572.755kJ/kg

$$\text{Paper waste (kJ/kg)} = (337 + 44.04) + 1428\,(6.196 - \frac{40.231}{8} + 9\,X\,0.211)$$

Heat Energy = 14,851.59 + 4,378.427 = 19,230.017kJ/kg

$$\text{Garden trimming (kJ/kg)} = (337 + 48.85) + 1428\,(6.394 - \frac{37.673}{8} + 9\,X\,0.371).$$

Heat Energy = 16,462.45 + 7,174.094 = 23,636.544kJ/kg

$$\text{Textile waste (kJ/kg)} = (337 + 51.68) + 1428\,(6.337 - \frac{39.389}{8} + 9\,X\,0.228)$$

Heat Energy = 17,416.16 + 4,948.561 = 22,364.72kJ/kg

$$\text{Wood waste (kJ/kg)} = (337 + 69.83) + 1428\,(9.89 - \frac{18.571}{8} + 9\,X\,0.084)$$

Heat Energy = 23,532.71 + 11,887.565 = 35,420.275kJ/kg

Therefore, the total Heat energy generated from the municipal waste in Auchi metropolis using equation 8 is presented below;

$$\text{Heat Energy (Auchi) kJ/kg} = (337 + 313.4) + 1428\,(38.35 - \frac{192.67}{8} + 9\,X\,1.54)$$

Heat Energy (Auchi) = 105,615.8 + 40,215.69 = **145,831.49kJ/kg**

3.1 Discussion

Indiscriminate disposal of municipal solid waste and low electric energy supplied are two major problems affecting the development of Auchi metropolis. Hence determination of heat energy from municipal solid waste in Auchi, Nigeria and its potential for electricity

Random truck sampling was used according to American Society for Testing and Materials (ASTM) in the collection of waste to the disposal site and characterized to determine the amount of chemical composition of the various municipal waste components in Auchi metropolis. The characterized waste components are food waste, plastics waste, paper waste, garden trimming waste, textile waste, and wood waste. For the purpose of energy estimation, (2) grams sample of the various characterized waste component were subjected to laboratory experiment to estimate the chemical composition of each waste element to determine the amount of carbon, hydrogen, oxygen, nitrogen, sulfur, and ash content hence determine the ultimate analysis as presented in Table 2. The ultimate analysis experimental values were subjected to Dulong's model that determined the Heat Energy values of 23,600.05kJ/kg on food waste, 21,572.755kJ/kg on plastics waste, 19,230.02 on paper waste, 23,636.54kJ/kg on garden trimming waste, 22,364.72kJ/kg on textile waste, and 35,420.28kJ/kg on wood waste having a total energy of 145,831.49kJ/kg.

In comparison with the experimental values, it was discovered that wood waste have the highest heating values 35,420.28kJ/kg for energy estimation in the metropolis. Similarly, the energy potential of the municipal waste in Auchi metropolis Nigeria 35,420.28kJ/kg justifies with the work of Shubhan Rath and Kumar (2017) on Kanpur City 12,260.61kJ/kg and that of Lawal Abdu Daura *et al*. (2018) on Kano metropolis 241,935.01kJ/kg among others.

4. Conclusion

Waste to energy experimentation needs to be implemented to make greater contribution in supplying renewable energy in Auchi, Nigeria while solving the country's municipal solid waste management problem in the coming decade. It is expected that the experience on the development of Waste to Energy in Auchi metropolis will offer some helpful lessons to other developing Areas in Nigeria.

In addition, power produced from the Waste to Energy activity can reduce the costly natural resources "fossil fuel" utilization in power generation. Fossil fuel are depleting day by day while on the other hand solid waste is increasing day by day, Waste to Energy solves both these problem by managing solid waste and producing electricity. Hence, Waste to Energy is a great step towards sustainable development as it saves coal resources which can be used by future generation while eliminating solid waste management problem which solves the land shortage problem and that extra land can be used for any fruitful work. Also leachate problem is solved by solid waste management as open dump cause leachate to develop which even pollutes the underground water that has health effects to the consumers.

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