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Assessing the Energy Potentials of Municipal Solid Wastes (MSW) in Ugbokolo

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ABSTRACT: The limited access to grid electricity and clean cooking fuels, as highlighted by global databases, emphasizes the significance of finding sustainable energy sources. The absence of waste-to-energy facilities in Ugbokolo, coupled with reliance on fossil fuels, and electricity from electrical distribution company for energy, underscores the urgency of exploring innovative approaches. The paper evaluates the MSW situation in Ugbokolo in terms of volume and composition, aiming to quantify the daily energy recovery potential. Ugbokolo is chosen as the study area due to its damaged aesthetic value from uncontrolled waste disposal and irregular electricity supply, the research seeks to address the inconveniences faced by its inhabitants. This study addresses the pressing challenges of electricity access and poor waste management in Ugbokolo, highlighting the critical need for sustainable solutions. Focused on the concept of waste-to-energy (WtE), the research explores the potential of converting municipal solid wastes (MSW) into heat and electricity, as an alternative means of electricity generation. It also advocates for a shift towards alternative energy sources, particularly Municipal Solid Wastes. The paper aims to contribute not only to electricity generation but also to waste management in Ugbokolo.

To determine the Energy Potential of municipal solid waste, the calorific values of dried weight of waste samples were first determined using stainless steel bomb cup (crucible) with respect to their residence time. The moisture content, Volume of acid used and change in temperature were also evaluated. Results showed that the calorific value (W) for oil palm fiber, food waste, sachet water bags, paper waste, sawdust (soft wood), sawdust (hard wood) were 14160.81, 10570.99, 14160.81, 11769.16, 11329.38 and 15031.91(kj/kg) respectively. The moisture content for oil palm fiber, food waste, sachet water bags, paper waste, sawdust (soft wood), sawdust (hard wood) were 31.1031, 20.6140, 13.3333, 8.9325, 11329.38 and 30.7189% respectively. The volume of acid used for oil palm fiber, food waste, sachet water bags, paper waste, sawdust (soft wood), sawdust (hard wood) were 6.50, 5.00, 2.50, 3.20, 2.70 and 5.20 % respectively. The total calorific value of the municipal solid work was estimated to be 80,492.55Kj/Kg which makes it suitable for waste-to-energy conversion.

Keywords: Electricity access, poor waste management, waste-to-energy (WtE), municipal solid wastes, Residence time.

I. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The shocking Statistics on electricity access and poor waste management system have been crucial challenges in Ugbokolo that motivate this study on waste- to-energy (WtE), a concept of utilizing the energy potential of waste to produce heat, electricity and biogas. It is an alternative means of electricity generation capable of gradually reducing the need for waste disposal on uncontrolled dumpsites [1]. The energy required, waste availability, composition and characteristics are basic variables for converting municipal solid waste into energy with regards to the basic principles [2]. Municipal Solid wastes (MSW) in this context refers to wastes collected from households, public institutions, schools and commercial premises that are disposed of on dumpsites excluding human faces [3].

Energy production in Ugbokolo had been focused mainly on electricity generation from Fossil fuels, solar and hydro power for lighting up homes, commercial institutions and some so on, but there has not been any waste-to- energy utilization.

The need for sustainable means of producing energy to meet the growing energy demand around the world has attracted research interest in recovering the energy potential from MSW, which had been considered as an effective

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way of reducing residual waste, with the added benefit of providing renewable energy to supplement conventional supplies [4].

The scope of this paper was to assess the MSW situation in Ugbokolo in terms of Volume and composition and to determine how much energy could be recovered from it on daily basis. Ugbokolo was chosen because its uncontrolled waste disposal has damaged its aesthetic value much to the inconveniences of its inhabitants. Ugbokolo also experiences irregular electricity supply that has been forcing businesses and public institutions to always prepare for power cuts and rationing of electricity supply. Limited access to energy is not only an obstacle to industrialization; it also reduces attraction to local and foreign investment, and severely productivity, educationally and economically. The World Bank sustainable Energy for all database on access to electricity revealed that in Nigeria only about 23.4% of the population has access to grid electricity [5]. It has been rated as one of the worst in the world, and the 2019 Energy progress Report revealed that less than 10% of population have access to clean cooking fuels and technologies [6]. According to the 2015 population and housing census, 64.7% of households rely on firewood for cooking, 32.1% uses charcoal while other sources including gas, kerosene, and electricity, etc account for only 3.2% [7]. A major challenge in addressing limited access to electricity is the lack of commitment in utilizing alternative energy source that are also environmentally friendly to diversify the energy, one of such resources is the Municipal Solid wastes (MSW). This lack of commitment is directly linked with weak and ineffective energy and policies that could lead to research and development towards alternative sources of energy. The waste collected and disposed of on these dumpsites will accumulate and eventually lead to environmental degradation through the release of contaminants including greenhouse gases.

To this end, as Ugbokolo has struggled for a proper waste management system, and stability in electricity supply, it is important to find an alternative means of energy supply. Energy from waste will not only compliment the use of electricity in Ugbokolo, it will also provide the much needed waste management solution in the town, and will contribute to the sanity.

II. LITERATURE REVIEW

The world is experiencing a rapidly growing population and rising public living standard, which leads to increases in the generation of municipal solid waste (MSW) and consumption of energy and goods. These activities result in changes in land use, deforestation, intensified agricultural practices, industrialization, and energy use from fossil fuels. The residues from such practices amount to green house gases that posses high risk to public health [8].

Solid waste generation rate has been attributed to increase in population and technological development [9]. Investigation has shown that in developing countries less than 50% of the MSW has been utilized for solid waste management. Therefore, solid waste management has become a hot issue due to environmental risks and challenges, which further has prompted researchers to consider MSW as a resource to be managed in a sustainable manner. Therefore, around the world to ensure sustainable MSW management, options such as mainly recycling, landfill with gas recovery, thermal, and biochemical conversion methods are being considered [10]. Recently, waste treatment processes generating energy from MSW in the form of heat, electricity, or transport fuels have received special attention and considered as waste to energy (WtE) options. Thus, the waste to energy approach is a promising energy alternative option for the future because of having potential to fulfill 10% of total global electricity demand [11]. WtE technologies have received much attention due to significant waste volume reduction along with the renewable energy production to meet the present as well as the future energy demands. Therefore, the authors have planned a systematic and in depth study for solid waste generation, composition and sustainable MSW management using biochemical and thermal energy conversions approaches. [12], [13] both reported that beside every individual been affected by the solid waste generation directly or indirectly, few authors have suggested any optimistic perspective regarding the increasing volumes of solid waste as providing free resources and employment opportunities, especially for the poor and the marginalized people.

Apart from greenhouse gases emission, improper waste management often leads to environmental degradation (i.e. water, air and soil pollution) and transmission of diseases. To combat these problems, several countries are following the waste to energy (WtE) approach, which significantly reduces the volume of waste and generates renewable energy.

Ugbokolo is one of the fastest-growing towns in the Benue state. This rapid development is aggravating the ever-increasing gap between demand and supply of energy. Identifying its waste composition and generation rate plays a great role in knowing its potential to produce renewable energy. The waste composition varies from one area to another.

2.1 BASIC EQUATIONS

(i) Determination of moisture content of samples

The moisture content of samples is determined using the following equation

Moisture Content (MC) % =
$$\frac{(Wws)g-(Wds)g}{(Wds)g} \ X \ \frac{100}{1} \quad (1)$$

Where W_{ws} = Weight of wet sample (g)
W_{ds} = Weight of Dry Sample (g)
Weight of Water = Weight of wet Sample – Weight of Dry Sample

(ii) **Higher /lower heating values**

$Q_h = 337C + 1428 (H – O/8) + 95S \quad (2)$

Where,
Q_h is is the higher heating value (kj/kg)
C is the carbon content (%)
H is the hydrogen content (%)
S is sulphur content (%)

The lower heating value (LHV) gives a better measure of heat released during actual operating condition and is determined from

$LHV = HHV- 0.0244(M + 9H) \quad (3)$

Where,
M= moisture content on dry basis
H = percentage of hydrogen

(ii)Determination of calorific values

The Calorific Values of the each waste sample are estimated using equation 4

$$W= \frac{\sum \Delta T - \emptyset - v}{m} \quad (4)$$

Where W = Energy value (calorific value),
ΔT = Change in temperature,
$\emptyset$ = constant (heat of combustion f wire) = 2.3J/g
V = volume of acid used,
M = mass of Sample
$\sum$ = standard energy value of the bomb calorimeter = 13039.308J

RELATED WORKS

[12] studied the energy potentials of municipal solid waste in osogbo metropolis. They investigated the volume of landfill gas and concentration om methane gas that will be produced via anaerobic digestion over a period and energy recovery possibilities were also estimated. Their results showed higher level of methane yield and stated that "the methane gas emitted can be harvested and utilized as as a renewable source of energy thereby mitigating pollution environmental occasioned by release of methane into the atmosphere from dumpsites most especially from developing countries towards ensuring a sustainable city."

[14] analysed the socio-productive infusion of collectors in the municipal solid waste management and provide detailed summary of waste recycling potentials in some developing countries and provide a frame work indicating the future practices and perspectives of municipal solid waste recycling.

The energy potential of the municipal solid waste in Buea was evaluated by [15]. The energy potential of the municipal solid waste in Buea was evaluated through land fill gas to energy and incineration technology methane emission from mussaka dumpsite for two decades was estimated using the inter-Governmental panel on climate change default method and Landfill Gas emission model. Providing crucial information for waste management investors

[16] studied the effect of temperature and residence time on calorific value of torrefied biomass. They worked on unprocessed biomass torrefaction process. The goal of their research was to study the effect of residence time and temperature on torrefaction process along with its mass yield on dry and ash free basis. Samples of sawdust were subjected to temperatures of 210^{o}C, 240^{o}C and 240^{o}C at 15, 30 and 45 mins residence times in inert atmosphere of nitrogen to produce torrefield biomass. Their results show increase in calorific value with increasing both temperature and residence time.

III. METHODOLOGY

The process of determining the calorific values of waste include; preparation of sample (shredding and drying) and the determination of the calorific values of the wastes. Samples were preheated by removing foreign and undesired Materials, all samples with the exception of sawdust were shredded with scissors before they were oven dried to reduce the moisture content. The initial and final weights of the samples are as

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shown in table 1 in appendix. In this process, (determination of calorific values) known dried weights of waste sample were fed into stainless steel bomb cup (crucible) with a spatula. A 10cm length of a combustible wire was measured and connected to the positive and negative terminals of the bomb passing through the sample. Also, 10ml of distill water was added to the bomb chamber to saturate the internal atmosphere. The bomb was then closed and about 25atm of pure oxygen was injected into the bomb. The whole bomb was immediately immersed in a bomb calorimeter before electrically ignited.

Figure 1(a): Sample of oil palm fiber

Figure 1 (b): Waste sample of sachet water bag

Figure 1 (c): Sample of food waste

Figure 1 (d): Sample of sawdust (softwood)

Figure 1 (e): Sample of sawdust (hardwood)
Figure 1(a – e) shows the pictures of the various waste samples

Energy is released by the combustion process and heat flows from these crosses, the stainless steel walls thus raises the temperature of the steel bomb, its contents and surrounding water jacket. The initial and final temperature was accurately recorded as shown in table 2 in appendix. The length of the unburned wire after thorough rinsing of the wire was measured and recorded. The acid produced was then titrated against 25cm3 of sodium trioxocarbonate iv. The color change indicates the end point or the volume of acid used. The samples were shredded, dried weighed and burning in a bomb calorimeter at the Chemistry Department laboratory, Benue State Polytechnic Ugbokolo. The calorific values were calculated using equation 1. Total Calorific value (W) for mix municipal solid waste was determined as the sum of the respective waste samples calorific values

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Figure 1: Laboratory Set Up Of A Bomb Calorimeter

3.1 Determination of the total calorific value (W) for mix municipal solid waste

The Total Calorific value (W) for mix municipal solid waste (W) was estimated as

$W_1 + W_2 + W_3 + W_4\ W_5 + W_6$

Where $W_{1\text{-}6}$ is the calorific values of the respective samples

W= 17626.30 + 14160. 81 + 10570.99 + 11769.16 + 11329.38 + 15031.91 =
80, 492.55kj/kg

Therefore, the energy potentials of the municipal solid waste is estimated to be
80, 492.55kj/kg

IV. RESULTS AND DISCUSSION

Figure 2 shows the bar charts of the moisture contents for the respective samples. The result shows that the various samples have different moisture contents. Wastes with different moisture content have different drying characteristics.

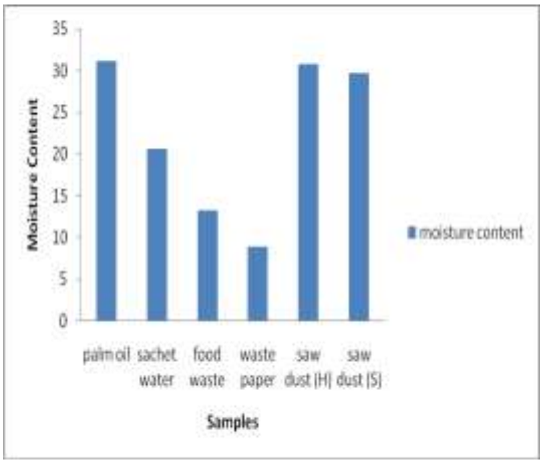

Figure 2: Graphical representation of moisture content

Those with high moisture contents require a longer drying time and more heat energy. The result of the analysis as shown on figure 1 indicates the moisture content of wastes ranging from 8.93% (paper waste) to 31.10%(oil palm fibre), respectively. The high or low percentage of waste moisture content is attributed to the nature of material or exposure to wet or dry environment.

Figure 3 shows the calorific values of waste samples obtained. The highest value of 17629.30Kj/ kg obtained from oil palm fibre agrees with [14], the wax (oily) component in the oil palm fibre sample is the reason for the increase in the burning rate and high calorific value.

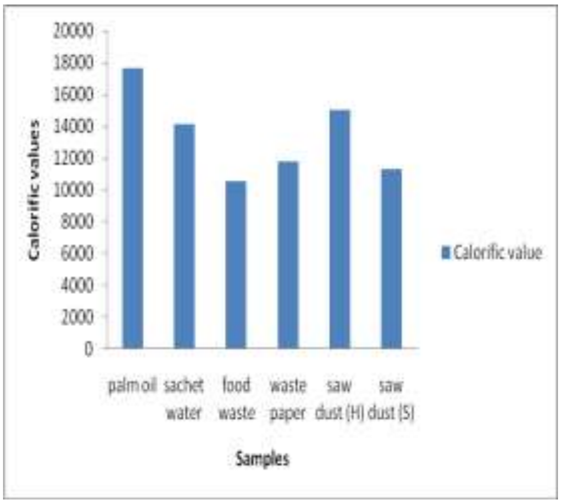

Figure 3: Graphical representation of Calorific value

Calorific value of a material is a function of carbonic acid; the presence and amount of carbon in the waste contribute to the high or low Calorific value of the waste. The result also shows different calorific values for the saw dust. The saw dust from hard wood has a calorific value of 15031.91kj/kg while that from soft wood has a value of 11329.38kj/kg. This is typified in the decreasing value range obtained. This agreed with [15] findings which observed that the Calorific value of different woods differs due to their difference in hardness.

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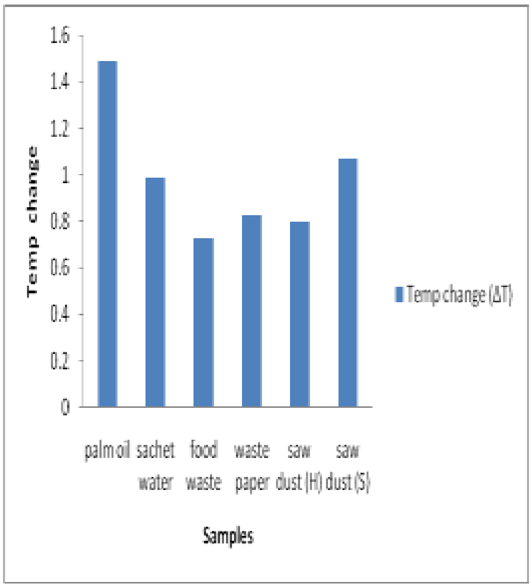

Figure 4: Graphical representation of Temperature change

The temperature change of various samples is as shown in figure 4 oil palm kernel has the highest temperature change during combustion with a value of 1.5 ^{0}C approximately the sample with least energy change is food waste having a value of 0.7 ^{0}C. The temperature change significantly affects the calorific values of samples.

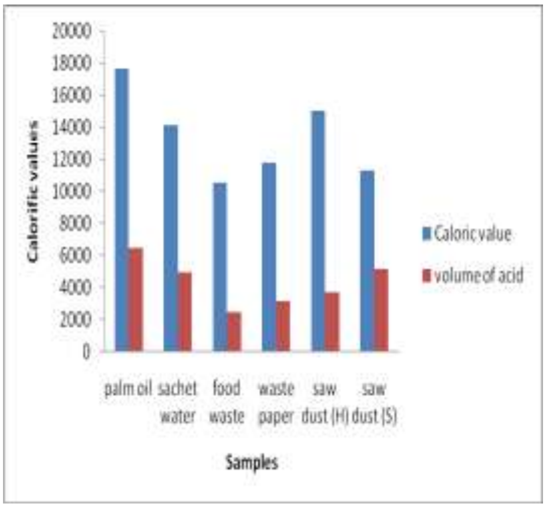

Figure 5: Volume of acid and calorific values

The graph of figure 5 shows the effect of volume of acid on the calorific values of the waste samples. Averagely the calorific values of the waste samples increases as the volume of acid increases. The presence of strong acidity favours the breakdown of C – C bonds hence, benefit the catalytic combustion [16].

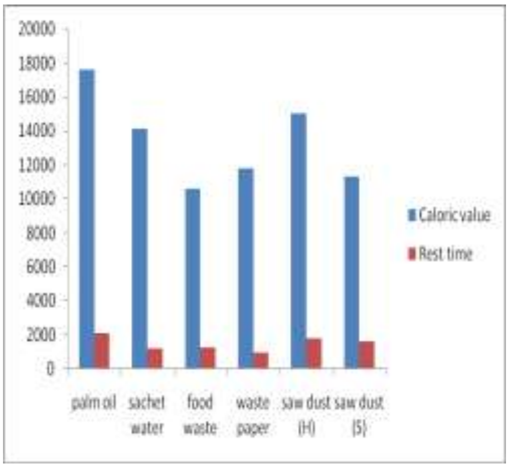

Figure 6: Residence time against calorific values

The figure 6 shows the effect of residence time on calorific values of the experimented samples. It shows that the calorific values of the samples increase with both temperature and the residence time. The residence time has much impact on the calorific value

4.2 ENERGY POTENTIAL OF MUNICIPAL SOLID WASTE (MSW)

The energy conversion potential of the MSW was estimated using the lower calorific value of waste because the amount of steam energy available is a function of the heating value of the waste. According to [17], Energy available is the determinant of the conversion efficiency of waste combustion. For 1 metric ton of mix municipal solid waste 335 kwh of electrical energy could be produced for 1 hour. The impact of this energy potential is dependent on the consumption pattern of the consumer for instance; if on average the typical consumption per household is 8kwh per day, 1 ton of waste is capable of providing the energy needs of about 50 households in Ugbokolo.

V. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

This study was motivated by the need to address two main problems affecting the people of Ugbokolo which are; unreliable supply of electricity and uncontrolled waste disposal. The results of the study indicated that the waste generated in Ugbokolo is enough and suitable to serve as sustainable fuel for a WtE technology.

5.2 CONCLUSION

The paper revealed that enough waste is generated in Ugbokolo with calorific values of

80,492.55Kj/Kg which makes it suitable for waste-to-energy conversion. This is because the LCV is required to be between 80,000KJ/kg and 90000KJ/kg to be suitable for waste-to-energy recovery by combustion according to [18], energy potential of municipal solid waste. Although the value is low it's is suitable to because there are modern designs that accept waste with LCV as low as 5000Kj/Kg.
Additionally this lower calorific value (LCV) could be improved by reducing the moisture content in the waste.

5.3 RECOMMENDATION

This paper has laid a foundation for further research that could lead to the implementation of Waste-to-energy technologies in Ugbokolo thereby reducing the rate at which wastes are disposed of on dumpsites in order to enhance clean, safe and healthy environment.

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Appendix

Table 1: Weight of Waste Samples

Waste Sample	Weight of dry sample (g)	Weight of Wet Sample (g)
Oil Palm fiber	1.106	1.450
Sachet Water bag	0.912	1.100
Food Waste	0.900	1.020
Paper Waste	0.918	1.000
Sawdust (Soft wood)	0.918	1.200
Saw dust (hard wood)	0.925	1.200

Table 2: Moisture Content of waste samples

Sample	Weight of dry sample (g)	Weight of Wet Sample (g)	Weight of Water (g)	Moisture Content (MC) %
Oil Palm fibre	1.106	1.450	0.3440	31.1031
Sachet Water bag	0.912	1.100	0.1880	20.6140
Food Waste	0.900	1.020	0.1200	13.3333
Paper Waste	0.918	1.000	0.0820	8.9325
Sawdust (Soft wood)	0.918	1.200	0.2820	30.7189
Saw dust (hard wood)	0.925	1.200	0.2750	29.7297

Table 3: Calorific value of the waste using bomb calorimeter

Sample	Weight of Sample (g)	Change in Temp (ΔT) °C	Length of burnt wire (cm)	Volume of acid (cm^3)	Resdence time	Energy of Machine $\sum$ (j)	Calorific Value CV (kj/kg)
Oil Palm fibre	1.106	1.496	9.50	6.50	35	13039.308	17626.30
Sachet Water bag	0.912	0.991	9.00	5.00	20	13039.308	14160.81
Food Waste	0.900	0.730	6.90	2.50	21	13039.308	10570.99
Paper Waste	0.918	0.829	6.80	3.20	16	13039.308	11769.16
Sawdust (Soft wood)	0.918	0.798	9.00	2.70	30	13039.308	11329.38
Saw dust (hard wood)	0.925	1.067	8.00	5.20	33	13039.308	15031.91