Characterisation and Thermochemical Energy Recovery Potential from Municipal Solid Waste in Gashua, Bade L.G.A. Of Yobe State, Nigeria

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ABSTRACT:

Articles on Characterisation and Energy Content inherent in the MSW and other related properties required for electricity generation were reviewed and energy potential of Gashua town municipal solid waste for electricity generation was determined based on solid waste incineration. Composition analysis of the solid waste samples from the dumpsite was carried out based on ASTM D5231-92 standard. The calorific value for the MSW in Gashua was estimated and it was found that the waste has a lower heating value of 1,597.81kJ/kg which indicates the feasibility of WTE plan such as incineration to electricity production. The electricity generation potential from MSW dumpsite show potential of 1899795.35kWh/day based on solid waste incineration. The average electricity generation per tonne of MSW is about 546.36 kWh/tonne. it can be concluded that: i. the annual quantity of MSW generation in Gashua was determined, ii. there is potential for generating electricity by incineration of MSW from the dumpsite, iii. electricity generation from MSW based on solid waste incineration would reduce total solid waste disposal, iv. there is economic viability of generating electricity from incineration of MSW from the dumpsite at affordable tariff rate**.** Furthermore, it is recommended that: i. this study helped in determining the potential for reduction in the total amount of MSW send to landfill, the emission of methane, and GHGs from MSW disposal site in Gashua. ii. If a WTE scheme is implemented in Gashua in accordance with the findings in this study, will promote the development of technologist to utilize MSW as energy source in the state in general.

Keywords: *Municipal Solid Waste; Solid Waste Management; Proximate analysis; Ultimate_analysis; Calorific value; Waste to Energy.*

Introduction

Municipal solid waste (MSW) more commonly known as trash or garbage consist of everyday items we use and then throw away, waste such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspaper, appliances, paints, and batteries (Leton & Omotosho, 2004). MSW comes from various sources such as homes, schools, hospitals, and businesses.

MSW is one of the most striking hallmarks of urbanization, as the world's rural communities keep migrating to urban centres, as the amount of MSW being generated in these urban areas happen to be growing faster than the rate of urbanization. Studies have shown that beside urbanization, there are other factors that contribute to an increase in the rate of generation of MSW. These socioeconomic/demographic factors according to Liu *et al*, (20019) include Gross Domestic Product (GDP), family or per capita disposable income, and consumption expenditure, economic development and improvement in the standard of living. In addition to these, a study by Mazzanti & Zoboli, (2008) states that other factors affecting waste generation include level of education, degree of industrialization, public habit, local climate, age of population and environmental law policies. Generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced (Hoomweg & Bhada-Tata, 2012).

Gashua is not an exception to the twin problems of poor solid waste management (SWM) and inadequate electricity supply that is generic to most cities in developing countries. The collection of waste in Gashua town is carried out by the Yobe State Environmental Protection Agency, (YOSEPA) Sanitary Board and Metropolitan Council. However; these local authorities have been overwhelmed by the increasing rate of waste generation, collection and transportation problems primarily due to overstretched facilities, shortages of the workforce and lean budget (Saleh *et. al*., 2012). YOSEPA manage the dumpsite by occasionally burning of MSW or just allowing it to decompose, this pollute the environment and also constitute a health hazard to the inhabitants immediate surrounding community and the society at large. However, if properly managed the MSW which is seen as a nuisance can be utilized in the generation of electricity which can greatly augment the amount of electricity allocated to the town from the national grid while also improving the environmental pollution and health hazards.

The literature review revealed that, no similar study has been undertaken in this study area thus, it would be of interest to study energy recovery strategies of waste treatment or disposal mechanism in the town to decrease the burden on the environment.

The increased rate in population of Gashua particularly due to the migration of the residents from Geidam, Kanamma and other part of Niger republic whose areas are under threats from insurgents has further added to the amount of MSW production of the town. Gashua is bedeviled by the dual concern problems of inadequate electricity supply and how to dispose of its waste in the eco-friendliest manner, which is not just unique to Gashua but the whole country. These problems of poor SWM practice and challenges in Gashua include: unscientific disposal method (open dumping), inadequate capacity for waste treatment or disposal mechanism, poor disposal habit of the residents and inadequate capacity of YOSEPA to collect and transport the waste properly to the main dumpsite. The implications include: leachate production arisen from the dumpsite, emission of bad odour and emission of methane and GHGs from the decomposition of organic components of the waste (YBSG, 2016).

A study undertaken in Accra Ghana, to explore the potential for utilizing MSW for energy recovery via thermochemical process The calorific value of MSW in Accra Ghana was determined using ASTM D5468 and the result showed that MSW in Accra is wet with calorific values ranging between 14MJ/kg-20MJ/kg and average energy recovery of about 40% (Julius *et al.,* 2005).

Gukop *et al.,* (2012) carried out a study, where he discovered that Nigeria generates 0.44kg/capita/day-0.66kg/capita/day of MSW with a waste density of 200-400kg/m^3. The study discovered that in most cases, the waste is poorly managed by directly burning it in open air at elevated temperatures, which liberates heat energy, inert gases and ash which could have been conveniently used for power generation and other applications.

Lawal (2014) study the characteristics of MSW and its potential for electricity generation in Bauchi town and its environs. The study by Lawal found that the per capital daily waste generation in Bauchi town was 0.19kg and the annual waste generation was found to be 35,000 tons. The study found that plastics and plastic bags were the highest proportion of the waste generated to about 27%, while inert materials which he termed as 'non-burning' materials were the least with just about 3%. In between, other materials i.e. textiles, grasses, papers, cans, animal remains and sand were 23%, 21%, 15%, 6%, 3%, 2% and 3% respectively. He was equally able to determine the calorific value of the waste in Bauchi to be 6.43MJ/kg, through it just about one-third of that of peat (15.9MJ/kg), it is sufficient for energy generation.

This study aimed to characterise and determine the potential of Gashua town MSW for electricity generation through the following objectives: i. to determine the annual quantity of MSW in Gashua ii. to determine the compositions of MSW generated in Gashua iii. To determine the energy content of MSW in Gashua for electricity generation iv. to determine the economic feasibility of generating electricity from MSW in Gashua

Material and Methods

Study Area

Gashua is a community in Yobe State located in the northeastern region of Nigeria, on the Yobe River, a few miles below the convergence of the Hadejia River and the Jama'are River. The average elevation is about 299 m. The population in 2006 was about 125,000 (Yobe State Government, 2016). The hottest months are March and April, with temperature ranges of 38°-43° Celsius. In the rainy season, June-September, temperatures fall to 23-28° Celsius, with rainfall of 500 to 800 mm. (Yobe State Government, 2016).

Collection of sample

Method of fresh garbage sampling Random truck sampling methods was applied in this work to identify the fresh waste characteristics. This method published by the American Society for Testing and Materials (ASTM D5231) and used to identify the waste composition of fresh garbage (incoming waste to landfill per day) was used.

Procedure for Proximate Analysis

Proximate Analysis was used to determine the moisture content. Volatile matter, and ash content. The MSW was mixed carefully and each composition was chopped and reduced to size. The analysis will be carried out based ASTM standard which is as follows:

i. Moisture content (ASTM D3173)

The percentage of moisture content was determined by hearing1g of waste sample to 105^0C for 1 hour in an oven. The sample was weighed before and after drying the sample.

$$\%MC = \frac{W_{1-W_2}}{W_1} \text{ X } 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

Where: MC is the moisture content; W_1 is the weight of a solid waste sample and dish before drying; and W_2 is weight of a solid waste sample and dish after drying in the oven.

ii. Volatile Matter (ASTM D3175)
Volatile matter was deduced from the difference of dried solid and ash content as:

$$\%V_m = \frac{D_w - A_w}{D_w} X\ 100 \ \ldots\ldots\ldots\ldots 2.2$$

Where V_m is the percentage of volatile matter; D_w is the weight of the residue and silica crucible before heating; and A_w is the weight of the residue and silica crucible after heating and cooling in a desiccator.

iii. Ash content (ASTM D3174)
The composition sample used in moisture content determination was weighed and placed in a furnace for 7 minutes at 925^0C. after the combination, the sample wasweighed to determine the dry ash content.

$$\% \text{ of Ash} = \frac{Weight\ of\ ash\ formed}{Weight\ of\ reidue\ of\ the\ sample} X\ 100\ .2.3$$

iv. Fixed Carbon
The percentage of fixed carbon was determined by subtracting the percentage of moisture content, volatile matter and ash content from 1 hundred (100) as:
$\%FC = 100 - (\%MC + \%Ash + \%v_m)$ (Amini *et al.*, 2011).

Procedure for Ultimate analysis

The ultimate analysis of solid waste typically involves the determination of the percentage of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and Sulphur (S) present in the combustible components of the MSW generated in the study area in accordance to ISO562 standard (Rominiyi et al., 2017).

I. Determination of Total Carbon

The percentage total carbon of the waste sample was determined directly by adding the volatile matter and the fixed carbon together as:

$$\%of\ Total\ Carbon = Volotile\ Matter + Fixed\ Carbon \ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

II. Determination of the percentage of Nitrogen

The nitrogen estimation in the solid waste sample was carried out by Kjeldahl method. The method involves taking one gram of the prepared solid waste sample which will be measured and recorded. The solid waste sample was heated with concentrated H_2SO_4 (tetraoxosulphate (vi) acid) in the presence of K_2SO_4 (Potassium tetraoxosulphate (vi) salt) and $CuSO_4$ (Copper (ii) tetraoxosulphate (vi) salt) in a long necked flask, called Kjeldahl flask, thereby converting the nitrogen in the solid waste sample ammonium sulphate. When a clear solution is obtained signifying that all the nitrogen present is converted to ammonium sulphate, the solution was treated with NaOH (Sodium hydroxide) solution. The ammonia formed was distilled over and absorbed in a known quantity of standard H_2SO_4 solution. The volume of an unused acid was determined by titration against a standard solution of NaOH. The amount of acid neutralized by liberating NH_3 from the solid waste sample will be evaluated as:

$$Titre\ Value\ (V_t) = V_1 - V_2\ (cm^3) \ldots\ldots\ldots\ldots\ldots 2.5$$

$$\%\ Nitrogen = \frac{v_{t\ x\ Normality x 1.4}}{w_t}\ X100 \ldots\ldots\ldots\ldots 2.6$$

Where: V_1 Volume of H_2SO_4 neutralized (cm^3)

V_2 Volume of H_2SO_4 neutralized in determination (cm^3)

Normality = -1.1905 x 10^{-4}

W_t = mass of the solid waste sample (g)

III. Determination of the Percentage of Sulphur

The Sulphur content was determined using ISO562 standard (Rominiyi *et al.*, 2017) 1 g of the sample was dissolved in 25 ml of water and pipette into 50 ml standard of flask followed by 20 ml geletine $BaCl_2$ solution and made up to 50 ml mark. The solutions were allowed to occur for 30 minutes. The absorbance of the standard solution (H_2SO_4) and the sample will be recorded as:

$$\%\ of\ sulphur = \frac{AxVxD_f}{Mass\ of\ the\ sample\ used} \ldots 2.7$$

Where: A = Absorbance

V = Total Volume

D_f = distillation factor

IV. Determination of the Percentage of Hydrogen and Oxygen

ISO562 standard (Rominiyi *et al.*, 2017) was used in determining the percentage of hydrogen and oxygen in the waste sample. This will be obtained from the difference between the sum of percentage total of carbon, nitrogen, Sulphur, and 100 as:

$$\%\ Hydrogen + \%\ Oxygen = 100 - \%(Carbon + Nitrogen + Sulphur) \ldots\ldots\ldots\ldots 2.8$$

Procedure for determination of Calorific Value.

The calorific value of the sample was determined with the aid of a standard bomb calorimeter (type Wagtech Gallen Kamp Auto bomb). The MSW was dried and chopped into smaller particles. The sample will be placed in a crucible, which was placed over a ring and fine magnesium wire touching the fuel sample across the electrodes. The lid was tightly screwed and the bomb will be fired with pressurized oxygen at about 25atm. The initial temperature wasrecorded, the electrodes will be connected to 6V battery and the circuit will be completed. As soon as the circuit completed and current supply will be switched on, the fuel sample in the crucible was burned with evolution of heat. The heat liberated burning the fuel was increase the temperature of the water and the maximum temperature attained will be recorded.

Heat liberated by fuel = heat absorbed by water and calorimeter

$$HCV = \frac{(W+w)X\Delta TXC}{m} \ldots\ldots\ldots\ldots 2.9$$

Where HCV = higher calorific value (kcal/kg)

C = specific heat capacity of water (cal/g ^{0}C)

W = weight of water in the calorimeter (g)

w = weight of fuel sample (g)

ΔT = change in temperature (^{0}C)

Energy Recovery from MSW

The potential energy recovery from MSW is expressed as (Sudhir, *et al*., 2010, Ityona *et al*., 2012)

$$Recoverable\ Energy = LHV\ X\ W\ X \frac{1000}{859.84}\ X\ \eta \text{ ……………..….2.10}$$

Where LHV = lower heating value

W = Amount of waste generated daily (tonnes/day)

η = efficiency of conversion

Utilization of MSW for energy recovery offer alternative to traditional landfill or dump by significantly reducing the waste volume and recovering energy inform of electricity, heat or fuels. WTE process recover energy from waste through either direct combustion such as incineration, pyrolysis and gasification or production of combustible fuels in the form of methane from anaerobic digestion in landfills or digesters, hydrogen and other synthetic fuels (Hefa *et al*., 2010).

The recovery of energy from waste offers a few additional benefits as follows;

i. The total quantity of waste get reduction by nearly 60% to over 90%, depending upon the waste composition and the adopted technology.
ii. Reducing demand for landfill or dumpsite, which are already scarce in cities, for waste disposal.
iii. The cost of transportation of waste to far away landfill site also reduced.
iv. Net reduction in environmental pollution.

WTE technologies utilized for harnessing the energy from waste are broadly categorized as Physical, Thermal and Biological methods.

RESULTS AND DISCUSSIONS

Solid waste characterization from random truck sampling method was done for a period of one week starting from Monday until Saturday which would cover the characteristics for whole week. The total amount of the waste generated in Gashua in the ten years of existence of the dumpsite was approximately 1255316 tonnes. Tables 1 and 2 show the annual quantity of waste generated in Gashua and its composition by weight.

Table 1: Annual Quantity of waste generated in Gashua main dumpsite

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Quantity(Tons)	18,012	109,396	110,920	113,168	97,568	126,052	131,548	132,671	135,401	1.39,018	141,562

Composition of Solid Waste

The result of the composition analysis was presented in table 1 and 2 which show that inert materials have the highest average percentage of 21.2%, followed by yard waste with 12.9%. plastic waste was 10.4% followed by food waste with10%, textile with 9.7, papers with

9.2%, wood with 84% and metals with 83%. The lowest is glasses with only 7.8% can be attribute of activities of scavengers picking this material fo4 recycling Onuigo (2019).

Table 2. Total weight composition of MSW sample collected in 6 days (kg)

Category	Total Weight of Sample Collected in 6 days (kg)							Percentage Weight (%)
	1	2	3	4	5	6	Average	
Papers	36.32	40.14	34.71	39.2	36.72	43.55	38.44	9.2
Plastics	58.42	61.23	62.92	57.95	59.71	53.61	50.64	10.4
Yard wastes	77.73	78.93	81.23	76.82	78.73	78.4	78.64	12.9
Food Wastes	44.21	42.59	43.52	46.72	41.25	42.59	43.48	10
Woods	37.20	39.18	38.44	39.21	40.08	47.25	38.56	8.4
Metals	39.33	39.14	37.25	38.14	36.25	43.41	38.92	8.3
Glasses	40.92	44.13	43.48	41.78	43.19	43.78	42.88	7.8
Textiles	48.98	47.25	50.12	51.03	58.92	50.58	49.48	9.7
Inert Materials	130.44	142.31	141.92	135.88	134.02	142.95	137.92	21.2

Energy Recovery Potential from MSW

The calorific value for the MSW in Gashua was estimated using equation 2.9, it was found that the waste has a lower heating value of 1,597.81kJ/kg which indicates the feasibility of WTE plan such as incineration to electricity production. The electricity generation potential from MSW dumpsite show potential of 1899795.35kWh/day based on solid waste incineration. The average electricity generation per tonne of MSW is about 546.36 kWh/tonne which is compared to a study by Daura (2016) which show that the average energy of generation per tonne of MSW combusted in United State is about 563kWh/tonne.

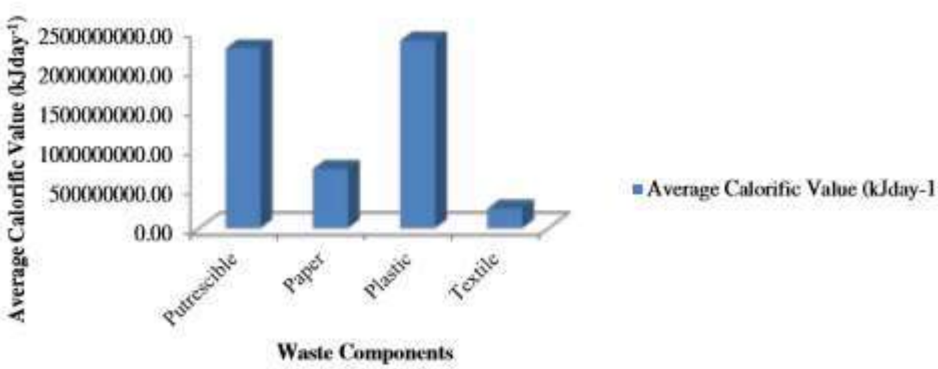

Figure 1: Calorific value of MSW generated daily

Conclusion

From the result of this study, it can be concluded that:

i. The annual quantity of MSW generation in Gashua was determined
ii. There is potential for generating electricity by incineration of MSW from the dumpsite
iii. Electricity generation from MSW based on solid waste incineration would reduce total solid waste disposal
iv. There is economic viability of generating electricity from incineration of MSW from the dumpsite at affordable tariff rate**.**

Recommendation

1. This study helped in determining the potential for reduction in the total amount of MS send to landfill, the emission of methane, and GHGs from MSW disposal site in Gashua.
2. If a WTE scheme is implemented in Gashua in accordance with the findings in this study, will promote the development of technologist to utilize MSW as energy source in the state in general.

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