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POTENTIAL OF KADUNA MUNICIPAL SOLID WASTE FOR ELECTRICITY GENERATION

Tasiu, M.[1] and Yola, I. A.[2]

[2]Department of Mechanical Engineering,Faculty of Engineering,Bayero University, Kano
Email : iayola.mec@buk.edu.ng; isaaliyuyola@gmail.
[1]No 96 Idi quarters,Bajoga ward Gombe, Gombe State. Emailmtacson14@yahoo.com
Corresponding author: Email**:** iayola.mec@buk.edu.ng

ABSTRACT

This study investigated the potential of energy generation of Kaduna State municipal solid wastes. Samples of municipal solid wastes from Kaduna North, Kaduna South, Igabi and Chikum dumpsites were collected. Proximate and Ultimate analyses were used to determine the chemical composition of the wastes. The results of the proximate analysis show that, percentage moisture content was in the range of (31.63 - 36.77 wt %), volatile matter in the range of (39.75 - 46.57 wt %), Ash content in the range of (5.32 - 14.84 wt %) and fixed carbon in the range of (9.78 - 12.12 wt %). From the Ultimate analysis, the percentages of Carbon, Hydrogen, Nitrogen, Oxygen and Sulphur in the dumpsites were found to be in the range of (47.31 – 52.60 wt %); (3.51- 4.09 wt %); (1.74 – 4.85 wt %);(28.12 – 32.68 wt % %) and (1.17 – 2.13 wt %) respectively. The average calorific value of the waste samples from the four dumpsites was also determined using ASTM D5468 and was found to be 29672.60 kJ/kg. The total energy potential of Kaduna metropolitan solid waste was found to be 1,524,087.24 kWh/day based on 818 tonnes/day capacity incineration plant. Therefore, this study concluded that the municipal solid waste of Kaduna metropolis may be suitable for energy production due to high calorific value of 29672.60 kJ/kg as well as low moisture content of (36.77 wt %).

Keywords: Kjeldahl method, Moisture, Volatile matter, Calorific Value

1. INTRODUCTION

Municipal Solid Waste (MSW) is defined as solid waste from residential (houses), commercial (businesses), institutional (hospitals) which does not include industrial, hazardous, construction and demolition (U.S EPI, 2019). Generation of MSW without proper evaluation is one of the greatest problems in most Nigerian cities and other developing countries (Tasiu and Yola, 2018). In developing countries, lack of knowledge, training and technologies to handle MSW are the challenges to solid waste management. The authorities in developing countries spend their limited financial resources to manage MSW in the areas where people with political power reside (Ayaa et al., 2014). Sustainable waste management is a challenge that is facing most developing countries, therefore, there is a need to reduce waste generation and increase material and energy recovery (Mutallab and Yola, 2019). The solutions to waste management problems in the modern era are provided by waste to energy (WTE), or energy from waste which is a process of generating energy in the form of electricity and/or heat from waste. This is done by the direct burning of mixed waste at elevated temperature (Ityona et al., 2012). Waste to energy (WTE) process recovers energy from waste through 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 and Yuanan, 2010). Most incinerators are not efficient in harnessing energy from the waste due to the fact that they are primarily designed to reduce the volume of waste (Abdu, 2015). Waste to energy incineration actually releases 33% more fossil-fuel-derived CO2 per unit energy than a gas-fired power station. There are two technological methods for processing/treatment of MSW. The first is the biological (composting and anaerobic digestion) and the second is the thermal option comprising incineration, gasification and pyrolysis, plasma pyrolysis and refuse-derived fuel (Hefa and Yuanan, 2010). The basic solid waste management system of collection, transportation, disposal and uti-

lization of municipal solid wastes remains highly inefficient and ineffective. This claims that, inefficient disposal and utilization of the wastes being dumped in an open space is the main factor influencing the susceptibility of residents along river Kaduna to floods annually. Therefore, setting up of power plants to utilize this municipal solid waste (MSW) as a fuel is one of the possible options.

2. MATERIALS AND METHODS

2.1. Materials/Equipment

The equipment used include electric oven (Gallenkamp OHF097.XX.1.5), muffle furnace (Carbolite CNF12/5,1), Bomb calorimeter set (G-Cussons P6310), desiccator, ceramic dish, spring weighing balance, Potassium hepta-oxodicromate (K2CR2O7) solution, plastic mats, non-corrodible air-tight container, Kjeldahl equipment and flask, concentrated trioxonitrate, perchloric acid, sodium hydroxide, hydrochloric acid, reflux condenser, asbestos, distilled water, Soxhlet extractor 80068-152-EA, Crucible (Gooch crucible), A retort stand, Pipette, Burette, Tripod stand, A measuring or mixing cylinder, A conical flask, Dryer, A separator funnel, Kjeldahl digestion and solid waste.

2.2. Methods

Proximate analysis of the waste generated in the selected dumpsites was conducted using the American Society for Testing and Materials standard (ASTM D3173-11, D3174-12 and D3175-11, 2013). The parameters evaluated were the weight percentages of moisture content, volatile matter, ash content, and fixed carbon. Ultimate analysis was used to determine the weight percentages of carbon (C), hydrogen (H), nitrogen (N), sulphur (S) and oxygen (O).

2.2.1 Proximate Analysis

Proximate analysis was used to determine weight percentage levels of moisture, volatile combustible matter, ash and fixed carbon contents in the dumpsites.

Moisture

The moisture content of the selected solid waste sample was determined using ASTM D3173-11 (2013). A mass of 1g of solid waste sample was placed in a pre-weighed dish and then weighed (W_1). The sample and the dish were placed in a controlled drying oven which was maintained at a temperature of about 105°C to 110°C for a period of 16 – 24 hrs. The dish and the dried sample were removed from the oven, and then cooled in a desiccator. The dried sample and the dish were finally weighed (W_2). The percentage moisture content was determined as a loss in weight before drying and after drying using the following equation.

(i) % Moisture content

$$\mathrm{MC} = \frac{W_1 - W_2}{W_1} \times 100 \qquad (1)$$

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

Volatile matter

The volatile matter was determined using ASTM D3175-11(2013). After moisture content was determined, the remaining residue of the sample was placed in a silica crucible with a porous silica cover to avoid oxidation and weighed (D_W) . The crucible with the residue was transferred into a muffle furnace (Carbolite CNF12/5, 1) then left for a period of 7 minutes at a temperature of about 950 $^{\circ}C$. The silica crucible with residue was removed from the furnace, cooled in desiccator and re-weighed (A_W) . The percentage volatile matter of the solid waste was determined using equation 2. The results are presented in Table 1.

(ii) % Volatile matter

$$V_m = \frac{D_w - A_w}{D_w} \times 100 \qquad (2)$$

where: V_m is the percentage of volatile matter, D_w is weight of residue with silica crucible before heating ; A_w is the weight of residue and silica crucible after heating and cooling in a desiccators.

Ash

Ash content was determined using (ASTM D3174-12, 2013). After the volatile matter was determined, the remaining residue with the dish was heated in a muffle furnace at a temperature of 750oC for 30 minutes and held until the sample was completely burnt to ash. The dish with the residue was then removed, cooled in a desiccator and re-weighed. The percentage of ash content was determined using the following equation,

(iii) % of ash content

$$= \frac{Weight\ of\ ash\ formed}{Weight\ of\ residue\ of\ the\ sample} \times 100 \qquad (3)$$

Fixed carbon

The percentage of fixed carbon (% FC) was determined by subtracting the percentages of moisture content,

volatile matter and ash from one hundred (100) as presented in equation 4. The results are presented in Table 1.

$$\% FC = 100 - (\%\text{MC} + \%\text{Ash} + \%V_m) \qquad (4)$$

2.2.2 Ultimate Analysis

Ultimate analysis was used to determine the weight percentage values of carbon, hydrogen, nitrogen, sulphur, and oxygen in the samples.

Nitrogen

A mass of 1.00 g of the solid waste sample was placed into Kjeldahl flask.20 ml of distilled water was added into the flask, swirled gently and allowed to stand for 30 minutes. 20 ml of hot concentrated sulphuric acid (purity = 98%, Specific gravity (S.G) = 1.84g). Potassium tetraoxosulphate (vi) (K_2 SO_4) and Copper (ii) (CuSO_4) were gently added into the flask. The flask was shaken until the contents were well mixed and the solution was allowed to cool after the digestion was completed. The flask was then connected to a distillation apparatus and heated slowly until the water evaporated and the mixture was clear. 0.1 M NaOH solution was used to neutralize H_2 SO_4 and evolved ammonium sulphate from the sample. The distillation continued for 30 minutes until the ammonia formed was absorbed into standard H_2 SO_4 solution. Few drops of methyl red were added and the excess H_2 SO_4 acid in the solution was titrated with 0.1M sodium hydroxide. The percentages of nitrogen in the samples were determined using equation 6. (Rominiyi et. al., 2017; Tadeusz,et al., 2013).The results are shown in Table 2.

The percentage of Nitrogen in the sample

$$\% N = \frac{(V_1 - V_2) \times Normality \times 1.4}{M_S} \times 100 \qquad (5)$$

where:

V_1 is the volume of H_2 SO_4 used for the sample; V_2 is the volume of H_2 SO_4 used for blank titration; M_s is the mass of sample

Sulphur

Nitric-Perchloric Acid digestion method was used to determine the percentage of sulphur in the waste. Amass of 1.0 g of the sample was weighed into a 50 ml dry digestion tube.5 ml of Diacid (2:1 Nitric acid: Perchloric Acid) was added into the digester and thoroughly swirled.. A small glass funnel was used to act as reflux condenser was placed over the sample and allowed to predigest at a temperature of 50 ℃ for one hour. The digestion tube was placed into a heating block port and left for one hour at a temperature of 150℃. The tube was removed and cooled .After cooling, 2 ml of Perchloric acid (HClO_4) was added slowly into the digestion tube and then placed back into a digestion block. The block temperature was raised to 235℃ for 2 hours until white fumes appeared. The digestion tube was removed from the digestion block and allowed to cool for 20 minutes in a hood. 10 ml of deionized water was added into the tube and then heated on a hot plate. The mixture was filtered and transferred into 25 ml volumetric flask. 10 ml from the extract was taken and prepared a standard curve for sulphur. (Rominiyi et al., 2017; Thakur et al., 2012). The results are presented in Table 2.

Percentage of sulphur in the solid waste

$$\% S = \frac{R \times V \times D_f}{M_s} \qquad (6)$$

Where

R is the sample concentration from the graph; V is the total volume; D_f is the dilution factor; M_s is the mass of sample

Carbon

A mass of 5g of the sample was grounded, sieved and then placed in a 250 ml flask. 10 ml of 1 N Potassium dichromate (K_(2) 〖Cr〗_2 O_7) solution was added to the flask and swirled gently to disperse the solid waste. 20 ml concentrated sulphuric acid (H2SO4) was added carefully from a measuring cylinder. The mixture was thoroughly swirled for about one minute and allowed to stand on a sheet of asbestos for about 30 minutes. 200 ml of deionized water, 10 ml of orthophosphoric acid and 1 ml of an indicator were also added into the mixture .0.5 ml ferrous sulphate was continuously been added into the mixture until the colour of the solution changed from blue to green. 0.5 ml of potassium dichromate was then added which changed the colour from green to blue. A droplet of ferrous solution was added rapidly and the flask was swirled until the colour of the solution changed from blue to green. (Kalenga, 2011). The results are presented in Table 2

The volume of potassium dichromate required to oxidize carbon in the sample

$$V = 10.5\left(1 - \frac{y}{x}\right) \qquad (7)$$

The percentage of organic carbon in the sample

$$OC = \frac{0.6V}{S} \qquad (8)$$

where V is the volume of potassium dichromate required to oxidize carbon in the sample

y is the total volume of ferrous sulphate solution used in the titration of carbon sample in ml.

x is the volume of ferrous sulphate solution used for standardization

Hydrogen and Oxygen

Hydrogen and Oxygen contents were determined using the following equations (Shilpi,2019)

The percentage of hydrogen in the sample

$$\%\ H = \left(\frac{2 \times mass\ of\ H_2O\ (moisture)}{18 \times mass\ of\ substance\ taken (sample)}\right) \times 100 \quad (9)$$

(9)

The percentage of oxygen in the sample

$$\%\ O = \left(\frac{16 \times mass\ of\ H_2O\ (moisture)}{\backslash 18 \times mass\ of\ substance\ taken (sample)}\right) \times 100$$

(10)

2.2.3 Calorific value

The calorific value was determined using digital bomb calorimeter (G-Cussons P6310). A mass of 0.65g of the sample was weighed and placed into the bomb calorimeter. Oxygen under pressure was then injected into the bomb calorimeter until the pressure reached 25 atm. The bomb calorimeter was placed into an adiabatic calorimeter bucket containing water. Ignition wire (fuse) of about 7cm long was attached to two electrodes of the bomb calorimeter and a thermometer was inserted inside the water jacket. The stirrer was then started and allowed to run for five minutes before the temperature readings were taken. The ignition button was then pressed at the fifth minute of the experiment. At the end of the fifth minute, a stop watch was used to record the temperature difference at one-minute interval for 3 minutes. Subsequent temperature readings were recorded continuously until the difference between successive readings became constant for at least three minutes. After the last temperature reading was taken, the calorimeter was stopped, the cover was lifted and the components were removed and wiped with a clean cloth. All the unburned pieces of fuse wire were also removed and measured in centimeters. The measured length was subtracted from the initial length 7cm to obtain the net amount of wire consumed during the firing. The results obtained from the experiment were used to determine the caloric value using the formula given in (ASTM D5468 - 02, 2016).

Gross calorific value of the fuel;

$$CV = \frac{\Delta T \times W^{-e}}{m} \quad (11)$$

$$\Delta T = (T_c - T_a)R_c \quad (12)$$

Radiation correction = R_c

$$R_c = nb = \frac{-c + b}{2} \quad (13)$$

where;

CV - Calorific value in (cal⁄g) , n - Number of minutes between the ignition; b - Rate of temperature fall in degrees per minutes at the end of the test; c - Rate of temperature rise in degrees per minutes at the beginning of the test; ΔT - Temperature rise in °C; e - Correction factor for heat of combustion of fuse wire (calorie) = 2.7 C_1 ; C_1 - length of fuse wire consumed (cm); m - mass of sample (g); and w - Energy equivalent of the calorimeter = 240 cal⁄°C. The results are presented in table 3.

2.2.4 Energy potential

Energy potentials of the municipal solid waste in the four dumpsites of Kaduna Metropolis were determined using the following formula given by (Sudhir et al., 2010; Daura 2016). The results are presented in Table 3.

$$E = LHV \times W \times \frac{1000}{859.84} \times \eta \quad (14)$$

where; E is the energy potential in kWh/day

W = the values of the daily waste disposal were obtained from (Tasiu and Yola, 2018)

LHV = Lower heating value of the solid waste

η = is the conversion efficiency which ranges between 22-28% (International Energy Agency (IEA), 2007). This study adopts 22% maximum ceiling conversion efficiency for electricity generation (Baxter and Baxter, 2013)

3. RESULTS

The results of proximate and ultimate analyses, calorific values, power potential and energy potential of Kaduna Metropolis Solid Waste are presented in Tables 1,2 and 3 respectively.

Table 1: Proximate Analysis of Kaduna Metropolis Solid Waste

Dumpsites	Moisture Con-tent (wt %)	Volatile Matter (wt %)	Ash Content (wt %)	Fixed Carbon (wt %)
Kaduna North	36.77	46.57	5.32	11.34
Kaduna South	31.63	44.58	13.12	10.67
Chikum	35.63	39.75	14.84	9.78
Igabi	33.23	41.15	13.50	12.12

Table 2: Ultimate Analysis of Kaduna Metropolis Solid Waste

Dumpsites	Carbon (wt %)	Nitrogen (wt %)	Hydrogen (wt %)	Sulphur (wt %)	Oxygen (wt %)	Ash (wt %)
Kaduna North	52.60	3.78	4.09	1.53	32.68	5.32
Kaduna South	48.27	4.85	3.51	2.13	28.12	13.12
Chikum	47.31	1.74	3.96	1.20	31.67	14.12
Igabi	48.06	4.04	3.69	1.17	29.54	13.50

Table 3: Calorific values, power potential and energy potential of Kaduna Metropolis solid waste

Dumpsites	Waste disposed (tones/day)	Calorific value (kJ/kg)	Power Potential (kWh)	Energy Potential (kWh/day)
Kaduna North	139.29	7577.40	11252.11	270050.63
Kaduna South	121.97	8210.70	10676.45	256234.88
Chikum	302.96	8445.80	27278.46	654683.09
Igabi	254.56	5438.70	14759.75	354234.00
Total	**818.78**	**29672.60**	**63966.77**	**1535202.60**

4. DISCUSSION OF RESULTS

4.1 Proximate analysis

Moisture content

The percentage weight of moisture content, volatile matter and ash with respect to the various waste dumpsites are presented in Table 1. The highest percentage moisture content of 36.77 wt % was obtained at Kaduna North, followed by Chikun with 35.63 wt%, Igabi with 33.23wt% and lastly Kaduna South with 31.63 wt%. The values of moisture content in the study area was found to be within the literature value of (15 - 40%) (Ozcan, 2016). Based on this study, it can therefore be

stated that, Kaduna MSW contains low moisture content of 36.77 wt %, which signifies higher calorific value probably due to high content of organic materials in the waste.

Volatile matter

The weight percentages of volatile matter at the dumpsites are presented in table 1. Kaduna North has the highest volatile matter of 46.57 wt%, Kaduna South with 44 wt %, Igabi with 41.15 wt % and lastly Chikum with 39.75 wt %. The dumpsites contained high percentages of volatile matter which showed that, the MSW contained large amount of useful gases which can easily be removed from the waste when heated. MSW with high volatile matter can easily be ignited at low temperature and it contains high heating value as reported by Abba, (2019).

Ash content

Table 1 presents the weight percentages of ash content found in the dumpsites at the study area. The highest percentage of ash was found in Chikum with 14.84 wt %, followed by Igabi with 13.15 wt %, then Kaduna South with 13.12 wt % and lastly Kaduna North with 5.32 wt %. Based on the results obtained, the ash content in Kaduna MSW was higher than the ash found in Minna which ranged between (0.49 – 12.58 wt %) as reported by Abimbola, (2019).

Fixed Carbon content

From the results presented in table 1, Igabi has the highest weight percentage fixed carbon of 12.12 wt %, Kaduna North with 11.34 wt %, then Kaduna South with 10.67 wt % and Chickum with the lowest value of 9.78 wt %. The fixed carbon found in Kaduna MSW was higher than the average fixed carbon of 5.27 wt % for Nigeria as reported by Ityno, (2012).

4.2 Ultimate analysis

Carbon content

From table 2, the municipal solid waste in Kaduna North has the highest carbon content of 52.60 wt %, followed by Kaduna South with 48.27 wt %t, then Igabi with 48.06 wt% and lastly Chikum with the lowest value of 47.31 wt %. The weight percentages of Kaduna MSW were closed to Minna MSW which ranged between (43.55- 45.13 wt %) as reported by Abimbola, (2019).

Hydrogen content

From the result presented in table 2, it can be observed that, Kaduna North has the highest hydrogen content of 4.09 wt %, followed by Chikun with 3.96 wt %, Igabi with of 3.69 wt%, and lastly Kaduna South with 3.51 wt %. The percentages of hydrogen in Kaduna MSW were within the range of (2.31 – 4.30 wt %) which was closed to Minna MSW(Abimbola, 2019).

Nitrogen content

From the results presented in table 2, Kaduna South has the highest nitrogen content of 4.85 %wt, followed by Igabi with 4.04 wt %, Kaduna North with 3.78 wt %, and lastly Chikum with 1.74 wt %. The percentages of Nitrogen in the Kaduna dumpsites were higher than Minna with (1.79 – 2.47 wt %) (Abimbola, 2019). The result showed that, higher percentage of Nitrogen oxide (〖NO〗_2) will be released in Kaduna when compared with percentage of nitrogen content that was obtained from Minna MSW.

Sulphur content

The percentages of sulphur in the dumpsites are presented in table 2. The results show that Kaduna South has the highest percentage of sulphur with 2.13 wt %, followed by Kaduna North with 1.53 wt %, then Chikun dumpsite with 1.20 wt %, and lastly Igabi with 1.17 wt %. The percentages of sulphur content in Kaduna MSW were higher than the percentages obtained in Minna with (0.16 – 0.98 wt %) (Abimbola, 2019). The result showed that, more sulphur oxide (〖SO〗_2) will be released in Kaduna when compared with percentage of sulphur content that was obtained from Minna MSW.

Oxygen content

From the result presented in table 2, it can be observed that, Kaduna North has the highest oxygen content of 32.68 wt %, followed by Chikun with 31.67 wt %, Igabi with of 29.54 wt%, and lastly Kaduna South with 28.12 wt %. The results showed that, the percentages of oxygen were very close to the observation made by Ityona, (2012) who reported that the average percentage weight of oxygen in Nigerian MSW was 30.92 wt %.

4.3 Calorific value

The result presented in table 3 indicates that, the average calorific value of Chikun MSW was the highest with 8,445.836 kJ/kg, followed by Kaduna South with 8,210.654 kJ/kg, then Kaduna North with 7577.4 kJ/kg and Igabi has the lowest calorific value of 5,438.748 kJ/kg. The highest calorific value was obtained from the area with high percentage of plastics waste, agricultural waste, and earth garbage. The results showed that, Kaduna south and Chikun dumpsites produced almost similar energy potential for setting up power plant. The calorific value of Kaduna north has also indicated a potential of producing energy from the solid waste generated. The total calorific value of the waste in the study area was found to be 29.673 MJ/kg and was higher than the minimum recommended calorific value of 7000 kJ/kg for setting up incineration plant with energy recovery as reported by Olisa and Ajoko, et al., (2018) and also higher than the literature value of 19.87MJ/kg as reported by Abimbola, (2019).

4.4 Power Potential

The power potential of Kaduna metropolis was determined using analytical method. Chikum has the highest power potential of 27277.75 kWh, followed by Igabi with 14759 kWh, then Kaduna North with 11252.11kWh and lastly Kaduna South with 10676.45 kWh. The total power potential in the dumpsites was found to be 63966.77 kWh. The power potential obtained from the study area can generate a reasonable amount of power to Kaduna State when compared with the present power supply of (160 – 350 MW) from the Power Holding Company of Nigeria (PHCN) as reported by Kaduna Investment Protection Agency (KADIPA), (2016).

4.5 Energy potential

The energy potential of Kaduna municipal solid waste was determined using analytical method. The results presented in table 3 show that, the energy potentials generated at the dumpsites in the study areas are 270,050.63 kWh/day, 256,234.88 kWh/day, 654,683.09 kWh/day, and 354,234.00 kWh/day for Kaduna North, Kaduna South, Chikun, and Igabi respectively, thus a total of 1,535,202.60 kWh/day of electricity can be generated from the four waste dumpsites. The result signifies high energy potential of Kaduna MSW when compared with the energy potential 115,968 kWh/day for Abuja MSW as reported by Adereju et al, (2019) and work done in Kano (Court road, maimalari, hajj camp and Ubagama dunpsites) on solid waste, in which a total of 805,579.61 kWh/day was obtained as reported by Abdu (2015).

5. CONCLUSION

The elemental composition of Kaduna MSW showed that, the wastes contained high carbon which ranged between (47.31 – 52.60 wt %) and high volatile matters ranging from (39.75 – 46.57 wt %) respectively. The municipal solid waste of the four (4) dumpsites have an average calorific value of 29672.60 kJ/kg. High calorific value was obtained as a result of high carbon and volatile contents in the wastes. The result of potential power generation showed that, substantial energy could be generated from municipal solid waste in Kaduna metropolis due to high calorific value of 29672.60 kJ/kg as well as low moisture content of 36.77 wt %. A power potential of 63966.77 kWh can be generated from the study area which is reasonable amount when compared to the present power supply of (160 – 350 MW) from the national grid to Kaduna State. Based on 818 tonnes/day capacity incineration plant, 1,535,185.44 kWh of electricity per tonne capacity will be generated.

REFERENCES

Abba, A.H.,Babangida,U.M.,Atiku,A.A. and Burmamu,B.R.(2019).Evaluation of Energy Potential from Municipal Solid Waste.Acase study of Yola, Nigeria.Federal University of Technoligy, Yola.

Abdu, L.D (2015). Energy Generation and Green House Gas Production Potentials of Municipal Solid Waste in Kano Metropolis, (PhD Thesis).Bayero University, Kano, Nigeria.

Abimbola, A. D.(2019). Evaluation of Impact of Solid Wastes and it's Potential as a Source from Minna and it's Environments, Nigeria. Acta Scientific Agriculture. 3(5):145 -152

Adereju,O.M.,Ombegemusse,U.G. and Dias,A.G.(2019). An optimization of the municipal solid waste Abuja for electricity power generation. International Journal of Energy Production Mgmt. 4(1):63 – 74.

ASTM D3173 -11, (2013). American Society for Testing and Materials. P.494-497.

ASTM D3174 -12, (2013). American Society for Testing and Materials. P.498-503.

ASTM D3175 -11, (2013). American Society for Testing and Materials. P.503-506.

ASTM D5468 - 02 , (withdrawn 2016). Standard Test Method for Gross Calorific Value and Ash Value of Waste. ASTM International, Harbor Drive, West Conshohocken, PA ,2007. United State.

Ayaa,F., Mtui, P., Banadda, N. and Van, I. J.(2014). Design and Computational Fluid Dynamic modeling of Municipal Solid Waste Incinerator for Kampala City Uganda. American Journal of Energy Engi-

neering. 2(3); 80 – 86

Baxcer, D. and Baxter, D. (2013).Factors affecting energy efficiency of waste to energy plants factors. 92(37); 166 – 174.

Daura, L.A.(2016). Electricity Generation Potential of Municipal Solid Waste in Kano Metropolis. Journal of Scientific and Engineering Research. 3(4); 157 – 161.

Hefa, C. and Yuanan, H. (2010). Municipal Solid Waste as Renewable Source of Energy, Current and Future Practice in China. A Journal of Science and Technology, 101 , 3816-3824.

Ityona, A., Kulla, D.M. and Nicholas G. (2012).Municipal Solid Waste Generation, Characteristics and Energy Potential in Nigeria. Journal of Energy in Southern Africa, 23 (3): 47-51.

International Energy Agency [IEA]. (2007). IAE Technology R&D Statistics. Retrieved from www.lea.org/stats/files/R&D.htm. 2018-11-09

Kaduna Investment Protection Agency (KADIPA),(2016). Retrived from kadipa.kdsg.gov.ng. 05/10/2020.

Kalenga, P.M.(2011). Characterization of Sulphur in South African Coal. Masters of Science Dissertation. University of the Witwater Srand Johannesburg.

Mutallab, M. and Yola, I. A.(2019). Characterization and Energy Potential of Municipal Solid Waste. A case Study of Katsina Metropolis. Nigerian Journal of Solar Energy. 30(1&2);80 – 86

Olisa,Y.P. and Ajoko,T.J (2018).Gross Calorific Value of Combustble Solid Waste in a Mass Incineration Plant, Benin City, Nigeria.Journal of Applied Sciences and Environmental Management. 22(9):1377 - 1380

Ozcan,H.K.,Guvec,S.Y.,Guvec,L. and Demir, G.(2016).Municipal Solid Waste characterization according to different Income levels: Acase study. Sustainability, Multidisciplinary Digital Publishing Institute (MDPI). 8:1088

Rominiyi,O.L., Olaniyi, T.K., Azeez, T.M., Eiche, J.F. and Akinola,S.A.(2017). Synergetic Effect of Proximate and Ultimate Analysis on the Heating Value of Municipal Solid Waste of A do-Ekiti, Metropolis, Southwest Nigeria. Current Journal of Applied Science and Technology(CJAST). 22(1) : 1-12

Shilpi N. (2019). Quantitative analysis/Chemistry Class II, Organic Chemistry-Some basic Principles and Techniques.

Sudhir, J., Venkata, K. and Prasada, R (2010). Waste to Energy – A case Study of Eluru City, AndraPredesh. Internationa Journal of Environmental Sciences, 1 (2): 151-162.

Tadeusz, M., Agustin G. A and Slawomir, W. (2013). The titration in the Kjeldahl Method of

Nitrogen determination: Base or Acid as Titrant. Journal of Chemistry Education. 90(2):191 – 197.

Tasiu, M. and Yola, I. A.(2018). Physical Analysis of Kaduna Municipal Solid Waste. 3rd National Engineering Conference on Bridging the Gap between Academia and Industry in Nigeria: Refocusing the Engineering Discipline-III. (ACICon2018). Faculty of Engineering, Bayero University, Kano. 14TH - 15TH November, 2018. Conference Proceedings. Pp.157 – 160.

Thakur, R. K., Baghel, S.S., Sharma, G. D., Sahu,R.K. and Amule,P.C.(2012). Laboratory Manual. Centre of Advanced Faculty Training, Department of Soil Science and Agricultural Chemistry Jawaharlal Nehru Krishi Vishwa Vidyalaya Jablpur 482 004(M.P)

United State Environmental Protection Agency (U.S. EPI).(2019). Advancing Sustainable Materials Management: 2017 Fact.