Available online www.jsaer.com

Journal of Scientific and Engineering Research, **2016, 3(4):157-161**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Electricity Generation Potential of Municipal Solid Waste in Kano Metropolis

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Abstract The Electricity generation potential of Municipal solid waste in Kano is presented in this paper. The composition analysis of municipal solid waste from four major solid waste disposal sites (dumpsites) within Kano municipality was conducted and energy content of the solid wastes were determined using empirical model equation based on proximate analysis. The energy content of the solid wastes from the four dumpsites were determined as 2185.56 kcal/kg (9.144 MJ/kg), 2132.73 kcal/kg (8.923 MJ/kg), 2322.21 kcal/kg (9.716 MJ/kg) and 2419.35 kcal/kg (10.125 MJ/kg) for Court road, Maimalari, Hajj camp and Ubagama waste dumpsites. Based on the energy content of the municipal solid waste, the electricity generation potential show a total of 805,579.68 kWh/day of electricity can be generated by incineration, with the dumpsites having the potentials to generate 198,973.68 kWh/day, 215,538.24 kWh/day, 258,400.56 kWh/day and 132,667.20 kWh/day for Court road, Maimalari, Hajj camp and Ubagama dumpsites respectively.

Keywords solid waste, composition, proximate analysis, Energy potential, calorific value

Introduction

Solid waste can be classified into Municipal (residential and commercial), industrial, construction and demolition wastes. Municipal solid wastes are the most non- homogeneous since they consist of the residues of nearly all materials used by humanity: Food and other organic wastes, paper, plastics, fabrics, leather, metals, glass and miscellaneous other inorganic materials [1]. Municipal solid waste (MSW) is produced due to human activities which may result in various environmental problems. The waste brings severe ecological contamination unless an appropriate solid waste management system is applied [2]. Municipal Solid waste (MSW) contains organic as well as inorganic matter and according to Intergovernmental panel on Climate Change municipal solid waste includes household waste, garden and park waste commercial and Institutional waste [3]. Solid waste management is an increasing problem, both because of rising waste generation and a declining supply of adequate disposal sites [4]. Management of municipal solid waste has become a major issue of concern for many underdeveloped nations especially as population increases. The problem is compounded as many nations continue to urbanize rapidly. 30 – 50% of populations in many developing countries is urban [5] and in many African Countries the growth rate of urban areas exceeds 4% [6]. It has been estimated that in 2006 the total amount of municipal solid waste (MSW) generated globally reached 2.02 billion tones, representing 7% annual increase since 2003. It is further estimated that between 2007- 2011 global generation of municipal waste will rise by 37,3% equivalent to 8% increase per year[7]. Nigeria with a population of over 140 million generates about 25 million tones of municipal solid waste per annum with a generation rate ranging from 0.66 kg/ capita day to 0.44 kg/ capita day, 60% of the waste is organic while about 8% are recycled [8]. It has been estimated that Kano Metropolis generates about 156,676 tonnes of solid waste per month and with a population of about 3,248,700 the per capita solid waste generation is about 0.56 kg/capita day [8], this makes Kano city the second to Lagos in terms of waste generation in Nigeria. Most of the waste generated which consists of plastics, paper wood, glass, metal and food remnants [9] are dumped in an open uncontrolled waste disposal sites scattered within the urban areas of the city which is typical of most developing countries where the dominant disposal method is open dumping compared to the wide use of sanitary landfills in western countries [10]. The waste disposal sites in Kano are characterized by odour and smoke coming from spontaneous fires (due to the presence of methane gas), which causes pollution problems to the environment and can lead to serious health hazards. According to Intergovernmental Panel on Climate Change(IPCC), gaseous emissions from solid waste disposal sites particularly methane can be a local hazard and is considered a green house gas(GHG) that contribute to global warming [11].

Due to the organic content and therefore high calorific value, energy can be recovered from organic fraction of solid waste (biodegradable as well as non biodegradable) through two methods [12] :

- Thermo chemical conversion; This process entails thermal decomposition of organic waste to produce either heat energy or fuel oil or gas
- Bio chemical conversion; this process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas (landfill gas) or alcohol.

The thermo chemical conversion processes are useful for wastes containing high percentage of organic non biodegradable matter and low moisture content. The main technological options under this category include incineration and pyrolysis/gasification. The bio chemical conversion process on the other hand are preferred for wastes having high percentage of organic biodegradable (putrescible) matter and high level of moisture/water content which aids microbial activity. The main technological option under this category is anaerobic digestion. The dominant waste to energy technology is mass burning because of its simplicity and low capital cost [13]. The most important parameter for determining the feasibility of energy recovery from solid waste is the energy content of the waste which is determine by the calorific value (heat value) of the solid waste The main objective of this study is to determine the energy potential of solid waste from solid waste disposal sites in Kano for electric power generation.

Methodology

Preliminary data collection of waste dumps

Preliminary data of waste dumps in Kano Metropolis were collected from Kano State Refuse management and Sanitation Board (REMASAB). Average monthly waste disposals in the four waste dump sites of Maimalari (Bompai), Hajj camp, Ubagama and Court road in the Kano Metropolis are shown in table 1.

Waste characterization/ physical composition

Characterization of waste at the disposal sites were carried out according to the American Society for Testing and Materials (ASTM D5231). The procedure involved random collection of waste from trucks loads in the amount of 15 to 20kg per unit. About 100 kg sample of solid waste was collected per day in each of the four dumpsites. At each dumpsite the collected sample waste was then spread on a polythene sheet and sorted into different categories of plastics, paper, textile material, glass, vegetable /Agricultural waste, metal and earth/ decayed matter. The categorized wastes were then weighted using a weighting scale and their percentage weight recorded. This procedure was conducted in the months of October, March and August (2012-2013) to cater for seasonal variations.

Proximate Analysis

Proximate analysis of the waste was carried according to ASTM 3173-3175 Standard methods. It involved the determination of moisture content, volatile matter, ash content and fixed carbon of the solid waste samples from the four dumpsites. 2 kg samples of solid wastes were collected from each dumpsite and taken to Laboratory for analysis.

Calorific Value

The calorific value or lower heat value (LHV) of the municipal waste was determined using proximate analysis models. Proximate analysis models were created based on the weight percentage of volatile matter and fixed carbon. The advantage of using proximate analysis data is that it gives result based on sample sizes [14] and the models do give an accurate estimation of the calorific values [15]. The model equations for predicting the calorific value of MSW based on proximate analysis are as follows [16],[17], [15]:

i. Traditional model

$$LHV = 45V - 6W \quad (1)$$

Where LHV: lower calorific value (kcal/kg)

V: combustible volatile matter (%),

W: moisture content (%)

ii. Bento's model

$$LHV = 44.75VM - 5.85W + 21.2 \quad (2)$$

Where LHV: lower heating value (kcal/kg)

VM: Volatile matter (%)

Energy generation potential of the municipal solid waste

The potential energy recovery from the solid waste is expressed as [18], [19]:

Energy recovery potential (kW) = LHV x W x 1000/859.84 x η (3)

Where LHV: lower heating value of the solid waste (kcal/kg); W: daily waste disposal (tonnes)

Results and Discussions

Preliminary data on solid waste disposal to the four dumpsites was collected as shown in Table1.

Table 1: Average monthly tonnes of waste disposals in four waste dumps of Kano metropolis in the years 2012-2013

Dumpsite	Average waste disposal (tonnes)	
	monthly	daily
Court Road	10,674.72	355.82
Maimalari	11,849.81	394.99
Haajj camp	13,046.88	434.90
Ubagama	6,429.65	214.32

Source: Kano State Refuse management and sanitation Board.

Solid wastes from different collection centers within Kano municipality are collected by trucks to these dumpsites. The data in the table 1 shows the average monthly and daily disposals of solid wastes the four major dumpsites in Kano, with Hajj camp dumpsite having the highest disposal rate of 434.90 tonnes/ day while Ubagama dumpsite having the least with 214.32 tonnes / day.

Physical composition

The result of composition analysis of the solid waste at the four dumpsites conducted in the months of October, March and August (2012-2013) are shown in table 2.

Table 2: Average percentage composition (%weight) of MSW

Category	Court road	Maiamalari	Hajj camp	Ubagama
Plastics	27.88	28.34	29.14	29.22
Paper	7.60	4.70	12.68	8.31
Textiles	11.48	5.13	8.41	10.18
Glass	1.87	3.63	1.57	2.94
Agricultural	21.78	15.54	18.69	17.58
Earth/ garbage	21.65	34.27	28.20	30.97
Metals	0.19	0.06	0.00	0.12
Food waste	7.49	8.33	1.32	0.67

Figure 1 shows the average percentage distribution of municipal solid waste composition at the four dumpsites.

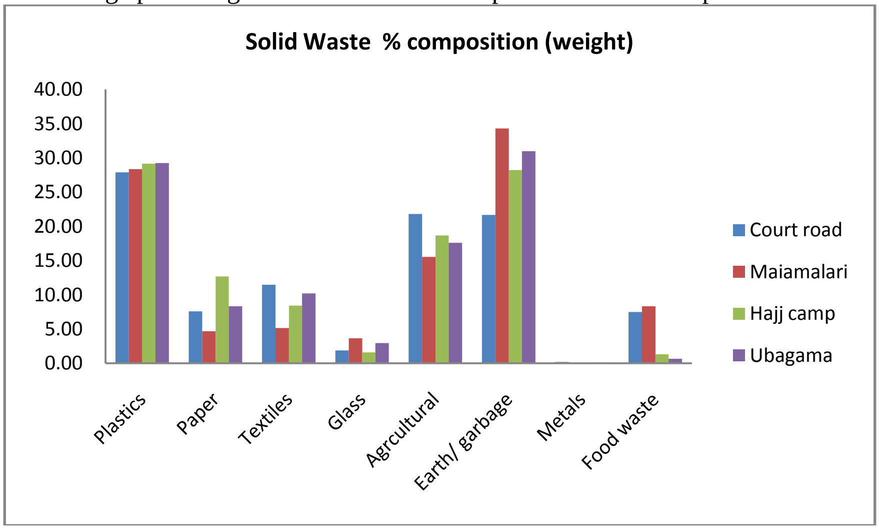

Figure 1: Average percentage solid waste composition.

Proximate analysis

Proximate analysis was conducted to determine the volatile matter, ash content, fixed carbon content and moisture content of the solid waste from the four dumpsites. The analysis was conducted for the solid waste collected in the months of October (2012), March and August (2013) from the dumpsites. The average result of the proximate analysis is shown in table 3.

Table 3: Average result of Proximate Analysis

ITEMS (% weight)	Proximate Analysis Court road	Maimalari	Hajj camp	Ubagama
Moisture	43.29	28.77	27.64	26.75
Volatile matter	54.34	51.23	55.29	57.33
Ash	40.82	45.93	39.99	36.44
Fixed Carbon	4.84	2.84	4.72	6.19

Calorific Value

The lower caloric value or lower heat value (LHV) of the municipal solid waste was determined using mathematical model based on the proximate analysis (equation 1). Table 4 shows the calorific values of MSW at the four dumpsites.

Table 4: Lower heat values (LHV) of MSW at the four dumpsites

Dumpsite	Lower heat values (LHV) kcal/kg	MJ/kg
Court road	2185.56	9.144
Maimalari	2132.73	8.923
Hajj camp	2322.21	9.716
Ubagama	2419.35	10.123

The lower heat values of the MSW in the four dumpsites ranges from 10.123 MJ/kg – 8.923 MJ/kg with MSW from Ubagama dumpsite having the highest LHV(10.123 MJ/kg) while MSW at Maimalari dumpsite have the lowest (8.923 MJ/kg). The World Bank has determined that for the viability of a waste to energy project (WTE), a minimum lower heat value of 6 MJ/kg throughout the season and an annual average of 7 MJ/kg are required (Amoo et al, 2013).

Using table 1 and from equation (3) the potential Power (electricity) generation is calculated as:

Potential power generation (kW) = 2185.56 x 355.82/24 x1000/859.84 x η

Where η is the conversion efficiency which ranges between 22 – 28% (IEA,2007). This study adopts 22% conversion efficiency. Therefore

Potential power generation = 2185.56 x 355.82/24 x1000/859.84 x 0.22
= 904,425.51 x 0.22/24
= 8,290.57 kW

Therefore potential electricity generation per day (kWh/day) = 8,290.57 x 24
=198,973.68 kWh/day

Potential electricity generation per ton of MSW (kWh/ton) = 198,973.68 / 355.82
= 559.20 kWh/ton

Table 13 shows the energy generation (electricity) and power potentials of the solid waste.

Table 13: Electricity generation potential of the solid wastes

S/NO.	Dumpsite	Potential Electricity generation (kWh/day)	Potential Electricity generation (kWh/ton)	Potential power generation(Electricity) (kW)
1.	Court road	198,973.68	559.20	8,290.57
2.	Maimalari	215,538.24	545.68	8,980.76
3.	Hajj Camp	258,400.56	594.16	10,766.69
4.	Ubagama	132,667.20	619.01	5,527.80
Total		805,579.68		33,565.82

The potential energy (electricity) generation from MSW incineration shows that a total of 805,579.68 kWh/day of electricity can be generated from the four waste dumpsites, with potentials of 198,973.68 kWh/day, 215,538.24 kWh/day, 258,400.56 kWh/day and 132,667.20 kWh/day for Court road, Maimalari, Hajj camp and Ubagama dumpsites respectively. Based on average household electricity consumption of 4200 kWh/year for Kano metropolis as estimated by Kano electricity distribution company (KEDCO, 2015), the total potential electricity generation of 805,579.68 kWh/day would supply about 70,009 households.

Conclusion/Recommendation

Municipal solid Waste disposal in landfills causes adverse environmental impacts, while incineration of the solid waste to produce energy would minimize or reduce the waste being land filled with significant environmental benefits. The analysis of municipal solid waste from four waste dumpsites in Kano show potentials for generating a total of 805,579.68 kWh/day of electricity by incineration, with the dumpsites having the potentials to generate 198,973.68 kWh/day, 215,538.24 kWh/day, 258,400.56 kWh/day and

132,667.20 kWh/day for Court road, Maimalari, Hajj camp and Ubagama dumpsites respectively. The total potential electricity generation of 805,579.68 kWh/day would supply about 70,009 households based on average household consumption of 4200 kWh/year.

As the generation of MSW is increasing in Kano and with exhaustion of current waste disposal sites within the municipality according to REMSAB, coupled with adverse environmental impacts of these waste dumpsites, it is recommended that waste to energy process such as incineration of the MSW to produce energy should be considered by the authorities.

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