Municipal Waste in Nigeria Generation, Characteristics and Energy Potential of Solid

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Abstract—**The generation, characteristics and energy potential of municipal solid waste for power generation in Nigeria is presented in this paper.**

Nigeria generates 0.44-0.66 kg/capita/day of MSW resulting in a waste density of 200-400 kg/m^{3}characterised by organic and inorganic sources.The direct burning of this wastes as a waste management option in the open air at elevated temperatures liberates heat energy, inert gases and ash which can be conveniently used for power generation where the net energy yield depends upon the density and composition of the waste; relative percentage of moisture and inert materials, size and shape of the constituents and design of the combustion system. MSW samples used in this study was obtained randomly from different dump sites in selected state capitals based on the spot sampling method of Corbit.An average calorific value of 17.23 MJ/kg with variable high water content was determined for MSW using a bomb calorimeter and on the basis of an incineration plant of capacity 1500 ton of MSW/day, 700kW/day of power can be generated

Index Terms—**Municipal solid waste, calorific value, waste to energy, proximate and ultimate analysis.**

INTRODUCTION

THE integrated solutions to problems of the waste management in the modern era provided by Waste to energy or energy from waste, by The direct burning of mixed waste in the open air at elevated temperatures in mass burning facilities liberates energy in the form of electricity or heat which can be conveniently used for power generation [1]. Traditionally this waste would have been disposed in land fill makes it attractive for developing countries.

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These new technologies have the potential to reduce the volume of the original waste by 90%, depending on the composition giving additional benefits of, a reduction our use for precarious natural resources can be realized thus cutting down our emissions of greenhouse gasses and by saving valuable land that would be otherwise be destined to become landfills and recovering land once sacrificed to the products of consumerism [1, 2, 3].

Solid waste management has emerged as one of the greatest challenges facing state and local government environmental protection agencies in Nigeria. The volume of solid waste being generated continues to increase at a faster rate than the ability of the agencies to improve on the financial and technical resources needed to parallel this growth. Solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste. As such most cities and towns have are characterised by waste disposal dumpsites situated all over.

The average waste density currently ranges between 280 to 370 kg/m^3 with waste generation rates ranging from 0.44 to 0.66 kg/capita/day[4]. The volume of solid waste in a few Nigerian cities for 1982, 1990 and the projected waste year 2000 respectively (table1) which shows the increase in solid waste generated in a few cities across Nigeria [5].

At a current population growth rate of 2.03% and 7% economic growth, energy consumption and waste generation in Nigeria is expected to soar over the next few years and the exploitation of this non-conventional energy locked up in urban solid municipal waste into grid energy can be taken advantage off. The heating value of mixed MSW is approximately about one-third of the calorific value of coal (8-12 MJ/kg as received for MSW and 25-30 MJ/kg for coal)[2]. The net energy yielddepends upon the density and composition of the waste; relative percentage of moisture and inert materials, which add to the heat loss; ignition temperature; size and shape of the constituents; design of the combustion system (fixed bed/ fluidised bed), etc [9, 12]. The objective of this paper is to assess the quantity (generation) and quality (physical and chemical) of Nigerian for power generation in Nigeria.

The challenges and changes in quantity and quality of the Municipal Solid Waste in Nigeria has reported in, [4-9]. The Federal Government of Nigeria laws and regulations in Nigeria [4], promulgated to protect the environment of which include the Federal Environmental Protection Agency Act of 1988 and the Federal Environmental Protection Agency (FEPA), created in 1999 under the FEPA Act decree's where each state and local government in the country set up its own environmental protection body for the protection and improvement of the environment within its jurisdiction, thus making Municipal solid waste management is a major responsibility of state and local government environmental agencies is reported in [4].

This paper presents the generation, characteristics and energy potential of municipal solid waste in Nigeria for power generation.

Table 1. Waste generation for 1982, 1990 and 2000, Source [5]

CITY	1982	1990	projected for 2000
Lagos	625399	786079	998081
Ibadan	350823	440956	559882
Kano	319935	402133	535186
Kaduna	257837	324084	431314
Onitsha	242240	304477	386593
Port-Harcourt	210934	265,129	352853
Aba	131903	169719	236703
Jos	99871	135272	197660
Warri	67447	91396	133531
Gusau	44488	57243	79835

II. Materials and Methods

The spot sampling method of [10] was adopted in the sampling and sorting protocol .The spot sampling method requires for the samples to be taken dump sites from the same source where an amount of waste (about 30–50 kg) is to be taken and the total amount collected will form a sample size of about 200 kg, which is then sorted. Five samples 10kg each of the raw MSW randomly from dump sites whose sources are generated by different activities from some selected state capitals which harbours the largest population and being the economic nerve of the respective states. The sampling was done between January and February, a period of dry season in most Nigerian cities. The sorting is carried out based on 5 different components as listed in table 4. Segregated waste components were weighed. Subsamples, each weighing 5 kg were taken from the composite samples and oven-heated at 85°C to constant weight for determination of moisture content.

Experimental determination of the physical and chemical characteristics, important parameters that determine energy recoverable from MSW was carried out by a proximate and ultimate analysis. Calorific value of MSW was determined in accordance to [11].

The calculation of the potential of recovery of energy from MSW is obtained from equation 1-4 which requires the knowledge of its calorific value and organic fraction, as in thermo-chemical conversion all of the organic matter, biodegradable as well as non-biodegradable, contributes to the energy output. Total waste quantity (W tonnes) calculated from a rough estimated of waste in place using equation 1[12].

Total Waste Land filled (W tonnes) = Urban Population x Waste Generation Rate (kg/person/year) x Fraction of Waste in Landfills or Open Dumps x Years of Land filling x 0.001 (1)

Energy recovery potential (kWh) = NCV x W x 1000/860 = 1.16 x NCV x W (2)

Power generation potential (kW) = 1.16 x NCV x W/ 24 = 0.048 x NCV x W (3)

Conversion Efficiency = η

Net power generation potential (kW) = η x 0.048 x NCV x W (4)

III. Results

The current waste generation rate for some Nigeria cites, the associated population of each city, and the tonnage per month is also given in Table 2.

Figure 1. Municipal Waste

Table 2. MSW generation in some Nigerian cities: Source[5,12]

City	*Population*	*Tonnage per month*	*Density (kg/m^3)*	*kg/capita/day*
Lagos	*9,000,000*	*255556*	*294*	*0.63*
Kano	*3,626,068*	*156676*	*290*	*0.56*
Ibadan	*3,565,108*	*135391*	*330*	*0.51*
Kaduna	*1,582,102*	*114433*	*320*	*0.58*
port Harcourt	*1,148,665*	*117825*	*300*	*0.6*
Makurdi	*292,645*	*24242*	*340*	*0.48*
Onitsha	*561,066*	*84137*	*310*	*0.53*
Nnsuka	*111,017*	*12000*	*370*	*0.44*
Abuja	*159,900*	*14785*	*280*	*0.66*
Abeokuta	*529,700*	-	-	*0.66*
Ado-Ekiti	*241,200*	*9 518*	-	*0.71*
Akure	*369,700*	-	-	*0.54*
Ibadan	*3,078,400*	*55200*	-	*0.71*
Ilorin	*756,400*	-	-	*0.43*
Aba,	*784500*	*236 703*	-	*0.46*
Uyo	*102400*	*20 923*	-	-
Maiduguri	*971700*	*850000*	-	-
Warri	*500900*	*66721*	-	-

Table 3. Composition of waste stream characteristics.

	Nnsuka	*Lagos*	*Makurdi*	*Kano*	*Onitsha*	*Ibadan*	*Maiduguri*	*Zaria*	Average
food/organics	59.8	63	59.3	58	56.9	58.5	60.8	58.8	59.38
Paper/ Paper/ polythene/polythene	25.72	45	23.22	38.42	39.11	37.6	35.6	39.07	35.46
textile	1.57	3.1	2.5	7	6.2	1.4	3.9	2.13	3.47
glass &metal	2.5	3	3.6	2	9.2	0.6	4.3	5.15	3.79
others(dust ash rubber, soil bones ceramics	9.4	19	14	22	15.4	8.9	31.3	4.33	15.545
Moisture content	20.79	28.36	20.27	18.88	21.17	23.52	17.95	18.33	21.15

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Table 4. Energy content of MSW

Components	Energy content (MJ/kg)
Organic / Pretiscible	11.59
Paper	10.14
Cardboard	11.033
Plastics	14.89
Polyethene	46.5
Metal glass and cans	
Textile	9.27
Net Calorific Value(MJ/kg) -	17.23
Moisture content	49.90%

Table 5. Proximate and Ultimate analysis

Proximate analysis(Wet)	Weight (%)	elemental analysis (Dry)	Weight (%)
moisture content	49.90	carbon content	51.33
volatile matter content	38.28	hydrogen content	6.77
fixed carbon content	5.27	nitrogen content	1.42
Ash content	5.25	oxygen content	30.92
		sulphur content	1.34

IV. Discussion

Waste characteristics influence the amount of energy within landfills. Different countries and regions have MSW with widely differing compositions

The population and generation rates for selected cities sampled in this study are presented in table 2. The waste composition and their percentages by weight are presented in Table 3. Further analysis of the sorted waste showed that constituents of the was quite similar except that the amount and proportion present in waste dump site differed in proportion for each sample and this greatly influenced by the type of activity dominant in the environment where the waste is generated and deposited.

The average percentage composition of various waste stream (Table 2) shows 43% organic component, 8% paper /cardboard/plastics and rubber, 26 % glass, 3% metal and cans, 2% textile materials, and 2% residue.

The average calorific value for the raw waste analysed without and drying or preheating is 11.38MJ/kg while for the oven dried MSW at 85^{o}C gave a calorific value of 17.38 MJ/kg and a moisture content of 49.90%. The collected waste sample reveal organic wastes containing high concentration of bio-degradable matter which are suitable for energy recovery through anaerobic de-composition or dried and combusted and a high proportion of polythene waste from sachet drinking water popularly known as "pure water", and shopping bags which has a calorific value of 14.89MJ/kg, the MSW obtained from southern Nigeria cities had higher moisture content than the samples collected in the northern part which is attributed to the relative humidity of the location of interest.

The ultimate and proximate analysis (Table 4) shows the chemical analysis by mass of important elements of the MSW sample. These are important parameters for technical viability of energy recovery through different any selected treatment routes. The proximate analysis, ultimate/elemental analysis and the calorific values are required for the design of a suitable incineration plant.

On the basis of a 1500 ton of MSW/day Incineration plant, MSW with average calorific values of 17.23MJ/kg, a conversion efficiency of 25% and 49% water content, the thermal treatment of MSW resulted in the generation capacity of 700 kWh of electricity per ton of MSW combusted. In practice, about 65 to 80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilised either for direct thermal applications, or for producing power via steam turbine generators (with typical conversion efficiency of about 30%). Modern incinerators can reduce waste volume by 97% and convert metal and glass to ash which is currently being researched to be used in materials development.

Incineration is extensively used as an important method of waste disposal; it is associated with some polluting discharges which are of environmental concern, although in varying degrees of severity. These can fortunately be effectively controlled by installing suitable pollution control devices and by suitable furnace construction and control of the combustion process. The challenges using waste as fuel is poised in the heterogeneous composition of each dumpsite, a Strong variations in the composition which is both regional and seasonal dependent, variations in the calorific value, possibilities of the and presence or production of hazardous substances

WTE adoption in Nigeria is at the moment not feasible due to lack of advanced technology, facility for separation at source, strength of solid waste management policy and enforcement, environmental education and awareness and income status of individuals among others are factors affecting solid waste scenario in Nigeria.

V. CONCLUSION

The generation, characteristics and the energy potential of MSW in Nigeria has been presented in this study. A calorific value of 17.23MJ/kg was obtained using a bomb calorimeter. On the basis of a 1500 ton capacity incineration plant a 700 kWh of electricity per ton of MSW combusted can be generated. Knowledge of the composition of specific landfills is very important. Lack of proper existing policies, legislation, waste handling and lack of awareness are obstacles for WTE Technology adoption in Nigeria.

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