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SUSTAINABILITY OF RENEWABLE ENERGY PRODUCTION FROM THE SOLID WASTE OF GOMBE METROPOLIS

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ABSTRACT
A study to assess the sustainability of renewable energy production from the solid waste of Gombe metropolis was carried out around the two officially designated waste dumpsites (INEX and GOSEPA), the result of the study shows that the waste at INEX dumpsite has a density of 300Kg/M^3, the site has the calculated capacity of 891,771.6M^3 and current capacity of 267,531.48 in tons, while waste at GOSEPA dumpsite has a density of 285Kg/M^3, the site also has the calculated capacity of 230,657.52M^3 and current capacity 65,737.39 of the waste at the dumpsite in tons. The result further shows that the initial year when dumping of waste commenced at INEX dumpsite was 2009 and as at 2018, 584,978 tons of waste have been deposited there with an average annual disposal of 64,997.56 tons per year, and the calculated year of the dumpsite closure of 2034. While GOSEPA dumpsite has 2005 as its year of initial dumping of waste and 225,259 tons of waste have been deposited there as at 2018 with an average annual disposal rate of 17,327.62 tons per year, and the calculated year of the dumpsite closure of 2051. Consequently this indicates the feasibility of waste to energy plant in Gombe metropolis, and through the incineration of municipal solid waste generated there, substantial quantity of electricity can be produced. The research therefore, recommend that government of Gombe State through the State ministry of Environment and Forest Resources should incorporate scavengers into the waste management stream, and also improve their surveillance mechanism to effectively regulate the activities of private waste management companies in order to harmonize the waste collection processes, transportation, treatment and disposal for the sustainability of the energy generation potentials from the incineration of the solid waste in Gombe metropolis, and the research further recommend another investigation to assess the economic sustainability of utilizing the solid waste generated in Gombe metropolis for energy generation.

Keywords: from the Solid Waste, of Gombe Metropolis, Sustainability of Renewable Energy Production

INTRODUCTION

Energy recovery from waste entails the conversion of mostly non-recyclable wastes into usable heat, electricity, or fuel through a variety of processes which include; combustion/incineration, gasification, pyrolysis, anaerobic digestion, and briquetting and landfill gas (LFG) recovery. These techniques help to reduce carbon emissions by offsetting the need for energy from fossil fuel as well as reduce methane generation from landfills (Bajracharya., Bahadur., Bajracharya & Singh (2016). There have been rigorous efforts to meet the increasing energy demand but relying on the traditional fossil fuels alone is synonymous to taking a great risk of backward trend in modern developmental strategies. The main reason behind this assertion is that fossil fuels and other conventional energy resources are not only limited but their global reserves is declining as each day closes. The global potential of municipal solid waste (MSW) as an energy source is as yet un-quantified (Allen, Lilian, Hugh. (2009). For development to be sustainable, delivery of energy services needs to be secured and have low environmental impacts. Sustainable, social and economic development requires assured and affordable access to the energy resources necessary to provide essential and sustainable energy services.

This may mean the application of different strategies at different stages of economic development. To be environmentally benign, energy services must be provided with low environmental impacts, including greenhouse gases (GHG) emissions and hence the need for efficient and sustainable energy source like energy from Municipal Solid Waste (MSW). One of the major problems facing growing cities in the developing countries worldwide is that of coping with the waste generated. Cities are very much battling with the increasing challenges of solid waste in particular and the battle is seemingly not being won (Malumfashi, 2011). Action to reduce the impact of climate change is critical, and limiting the increase in average global temperatures to less than 2°C requires concerted global action both locally, nationally and internationally. Renewable energy has been growing rapidly in the last decade, becoming an important component of energy supply (OECD/IEA 2010), it plays a key role in mitigating global greenhouse gas emissions by radically lowering the emissions profile of the global energy system (IRENA 2015). To properly

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analyze and plan the use of renewable energy in African countries, there is need for accurate and documented estimates of their renewable energy potential, as well as to identify the most suitable locations for investment and deployment in renewable energy technologies. The accuracy of this information correlates directly with the risk taken in the decision-making process. Accurate data strengthens each country's national strategy to deploy renewable energy technologies (IRENA-DBFZ 2013). This means solid waste now contains an increasingly complex mix of materials, including plastics, precious metals and hazardous materials that are difficult to deal with safely (EU, 2010).

Rapid urbanization and industrialization coupled with the increasing growth in population has led to a sharp rise in the quantity of municipal solid waste (MSW) generation in most of cities of the developing nations (Arugula., Singh., Balasubramanian., & Rajkumar., (2015). Amber., Kulla., & Gukop., (2012) maintained that, at a population growth rate of 2.03%, energy consumption and waste generation in Nigeria is expected to soar over the next few years, so also in Gombe metropolis, which is one of the most populous metropolitan city in the northeastern part of Nigeria, with population growth rate of 3.2% and urbanization rate of 3.5% per annum (NPoP'C,2009) leading to higher MSW generation of 21,297 tons and 5,832 tons per month for INEX and GOSEPA dumpsites respectively (INEX, 2018, & GOSEPA, 2018), causing a lot of problems to man and the general environment. UNEP (2009) reported that the collection, transportation, treatment, and disposal of municipal solid wastes, particularly wastes generated in medium and large urban centers, have become a relatively difficult problem to solve for those responsible for their management. The problem is even more acute in economically developing countries like Nigeria, human resources are under-utilized, while financial as well as other critical resources generally are scarce. In these countries the standards of waste management is still poor and outdated, with poor documentation of waste generation rates and its composition, inefficient storage and collection systems, disposal of municipal wastes with toxic and hazardous waste, indiscriminate disposal or dumping of wastes and inefficient utilization of disposal site space, and these has contributed greatly to river pollution and also serve as one of the sources of greenhouse gases which is a major contributor to climate change (Ayuba., Abd., Sabrina., & Azmin., 2013). Ahmed., Muhammad., Nasir., & Hussain (2012) reported that there is enormous increase in the quantum and diversity of waste materials generated by human activities and their potentially harmful effects on the general environment and public health.

LITERATURE REVIEW

Biomass is a renewable energy source from living plants and organic waste which are made by plants, human, marine life, and animals. Based on Tester (2015), the main advantage of biomass is availability, as it can be readily found in all places. Many kinds of energy can be produced from biomass: electricity, cooking heat, chemical feedstock etc. As a feedstock, biomass has lower sulfur content than coal, and a lower emission is produced by combustion (Ngo and Natowitz, 2009). Nigeria is the most populated nation in Africa, with a 2020 population estimate of 205,740,000 people, growing annually at an estimated rate of 3% and generating 0.55 to 0.58 kg of municipal solid waste per person per day, Nigeria can be said to be equally experiencing significant waste-related environmental problems can be said to have begun in the period when Nigeria gained independence, become rapidly urbanized, and thus generated more solid waste than nature can absorb or that Nigeria can efficiently dispose. MSW is produced daily all over the world, and it is a renewable energy resource with the potential to produce energy via WTE plants, while also reducing the volume of waste. WTE can address the twin issues of land use and pollution from landfills and the well-established environmental perils of fossil fuels known as greenhouse gas emissions (GHG) (Amoo et al., 2013).

Solid Waste generation rates is the average amount that each person throws away, it varies widely within and between locations. The generation rates depend on income levels, socio-cultural patterns and climatic factors (UNEP, 2009).The rate at which the cities generate municipal solid waste is increasing due to rapid population growth and urbanization; this is more peculiar to cities in developing world. It is important to have adequate information about solid waste generation if a wise decision about future waste management is to be made. Solid waste generation is correlated with the population of an area or city, due to which bigger cities with high population tend to generate more waste than those with low population. The total amount of solid waste generated per person per day in many cities of developing countries has noticeably increased as well. It has almost doubled during last ten years from 0.64 kg to 1.2 kg and is expected to reach 1.42 kg by year 2025 (I.E.A, 2003). High income countries generate more waste per person compared to low income countries due to differences in GDP. It is worthy to note that even within the same country or region the per capita generation may differ due vibrancy of economic activities, consumption pattern and local climate. In Nigeria (I.E.A, 2003) reported that the waste generation rates ranged from 0.44 to 0.66 kg/capita/day but this varies from city to city and even within cities.

MATERIALS AND METHODS

The Study Area

Location of the Study Area

Gombe city the capital of Gombe State is located in the northeastern part of Nigeria on coordinates 10017'N 11010'E. It has a total area of 52Km^2 (20sq mi) with a population of 377,341 people (2006 census), and the projected population of 534,314.856 people (Adamu et al., 2017).

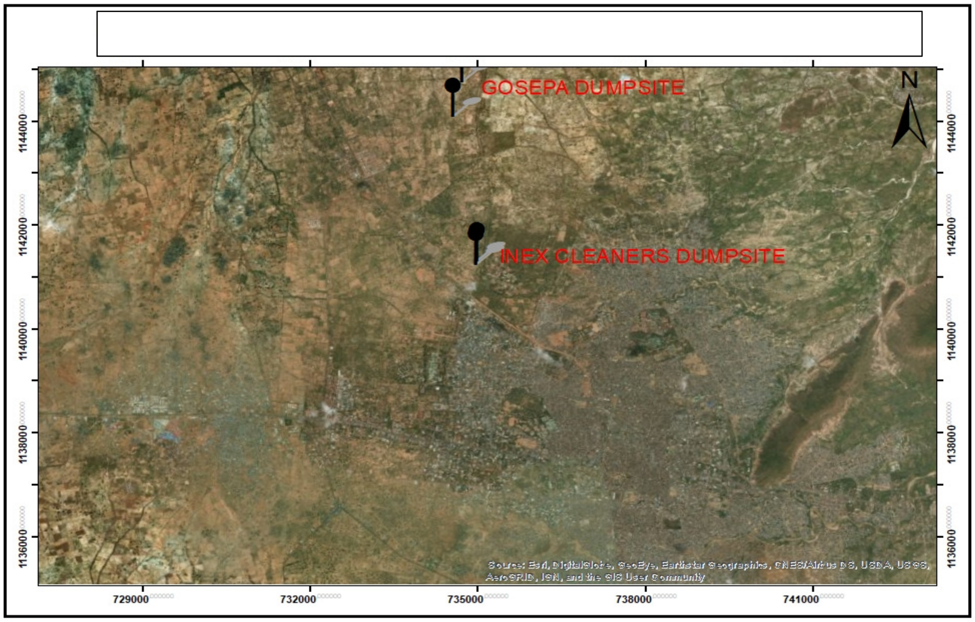

Plate 1: Image of Gombe Metropolis Showing INEX Cleaners and GOSEPA Dumpsites (in red colors)

i. INEX Cleaners dumpsite is a sanitary landfill located opposite Federal College of Education (Tech) Gombe along Ashaka road in Gombe metropolis. It is located on coordinate 11°8′36.757″E 10° 20′45.095″N and 11°8′42.73″E 10° 21′6.575″N respectively, and covers an area of 89,177.16m^2.
ii. **GOSEPA dumpsite** is a burrow pit located adjacent to Grave yard along Ashaka road in Gombe metropolis. It is located on coordinate 11°8′50.898″E 10° 19′15.474″N and 11°8′50.522″E 10° 19′13.164″N respectively. It covers an area of 28,832.19m^2.

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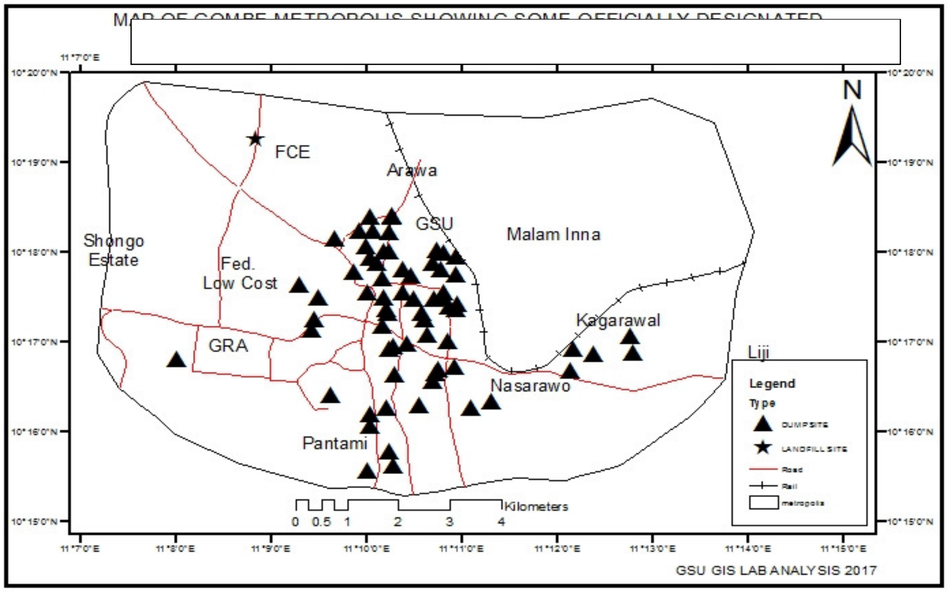

Figure 1: Map of the Approved Waste Collection Centres in Gombe Metropolis

Plate 2: Sorting of Waste at GOSEPA Dumpsite

Plate 3: Measuring the absorbance of the MSW samples using Ultraviolet-Visible Spectrophotometer

RESULTS

Energy Generation Potentials of Gombe Metropolis Solid Waste

Table 1: Proximate Analysis of Solid Waste from INEX Cleaners Dumpsite (2019).

Table 1: shows the result of the proximate analysis of the INEX dumpsite. The result indicated that INEX had 38.37% Moisture Content; 34.29% Ash Content; 49.40% Volatile Matter; 7.20% Fixed Carbon.

Table 1: Proximate Analysis of Solid Waste from INEX Cleaners Dumpsite (2019).

	Proximate Composition (%)			
Samples	Moisture content	Ash content	Volatile matter	Fixed carbon
INEX	38.37	34.29	49.40	7.20

Source: Laboratory Analysis Adamu, 2019.

Table 2: shows the result of the proximate analysis of the GOSEPA dumpsite. The result indicated that GOSEPA had 55.01% Moisture Content; 37.30% Ash Content; 42.01 Volatile Matter; 8.44% Fixed Carbon.

Table 2: Proximate Analysis of Solid Waste from GOSEPA Dumpsite (2019).

Samples	Proximate Composition (%) Moisture content	Ash content	Volatile matter	Fixed carbon
GOSEPA	55.01	37.30	42.01	8.44

Source: Laboratory Analysis Adamu, 2019.

Table 3: Ultimate Analysis of Solid Waste from INEX Cleaners Dumpsite (2019)

Table 3: shows the result of the ultimate analysis of the INEX dumpsite. The result indicated that INEX had 4.76% Total Nitrogen; 0.092% Sulphate; 30.8643% Carbon; 3.142% Hydrogen; 26.8517% Oxygen.

Table 3: Ultimate Analysis of Solid Waste from INEX Cleaners Dumpsite (2019)

Samples	Ultimate Analysis (%)				
	Total Nitrogen	Sulphate	Carbon (C)	Hydrogen (H)	Oxygen (O)
INEX	4.76	0.092	30.8643	3.142	26.8517

Source: Laboratory Analysis Adamu, 2019.

Table 4: Ultimate Analysis of Solid Waste from Gombe State Environmental Protection Agency (GOSEPA) Dumpsite (2019)

Table 4: shows the result of the ultimate analysis of GOSEPA dumpsite. The result indicated that GOSEPA had 6.52% Total Nitrogen; 0.089% Sulphate; 32.2379% Carbon; 4.6570% Hydrogen; 19.1961% Oxygen.

Table 4: Ultimate Analysis of Solid Waste from Gombe State Environmental Sanitation and Protection Agency (GOSEPA) Dumpsite (2019)

Samples	Ultimate Analysis (%)				
	Total Nitrogen	Sulphate	Carbon (C)	Hydrogen (H)	Oxygen (O)
GOSEPA	6.52	0.089	32.2379	4.6570	19.1961

Source: Laboratory Analysis Adamu, 2019.

Table 5: LHV (kcal/kg) values from the Proximate Analysis Model Equations for INEX

Table 5: shows Traditional model equation 2.2 INEX waste samples had LHV of 1,992.8kcal/kg. While using Bento's model equation 2.3 INEX waste samples had LHV of 1,964.9kcal/kg.

Table 5: LHV (kcal/kg) values from the Proximate Analysis Model Equations for INEX

		LHV (kcal/kg) using model equations	
		Traditional Model equation 2.2	Bento's Model equation 2.3
S/N	Dumpsites		
1	INEX	1,992.8	1,964.9

Source: Laboratory Analysis Adamu, 2019.

Table 6: LHV (kcal/kg) values from the Proximate Analysis Model Equations for GOSEPA

Table 6: shows Traditional model equation 2.2 GOSEPA waste samples had LHV of 1,560.4kcal/kg. While using Bento's model equation 2.3 GOSEPA waste samples had LHV of 1,536.9kcal/kg.

Table 6: LHV (kcal/kg) values from the Proximate Analysis Model Equations for GOSEPA

		LHV (kcal/kg) using model equations	
		Traditional Model equation 2.2	Bento's Model equation 2.3
S/N	Dumpsites		
1	GOSEPA	1,560.4	1,536.9

Source: Laboratory Analysis Adamu, 2019.

Table 7: Electricity and Power Generation Potentials of the Solid Waste from the Two Dumpsites in Gombe metropolis under Study (2019)

Table 7: shows the total potential electricity generation of 439,577 kWh/day from both INEX (361,963.2kWh/day) and GOSEPA (77,613.8kWh/day) by burning 909.13kWh/tonnes of solid waste with INEX having (509.88kWh/tonnes) and GOSEPA (399.25kWh/tonnes) which translate into generating 18,315.7kW with INEX producing (15,081.8kW) and GOSEPA (3,233.9kW).

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Table 7: Electricity and Power Generation Potentials of the Solid Waste from the Two Dumpsites in Gombe metropolis under Study (2019)

S/N	Dumpsites	Potential Electricity Generation (kWh/day)	Potential Electricity Generation (kWh/tonne)	Potential Electricity Generation (kW)
1	INEX	361,963.2	509.88	15,081.8
2	GOSEPA	77,613.8	399.25	3,233.9
Total		439,577	909.13	18,315.7

Source: Laboratory Analysis Adamu, 2019.

Table 8: Calculated Capacities of the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

Table 8: shows that the waste at INEX dumpsite has a density of 300Kg/M^3, calculated capacity of 891,771.6M^3 in M^3 and a calculated capacity of 267,531.48 in tons, while waste at GOSEPA dumpsite has a density of 285Kg/M^3, calculated capacity of 230,657.52M^3 in M^3 and a calculated capacity 65,737.39 of the waste at the dumpsite in tons.

Table 8: Calculated Capacities of the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

S/N	Dumpsite	Density (Kg/M^3)	Average depth (M)	Area(M^2)	Calculated Capacity(M^3)	Calculate Capacity(Tons)
1	INEX	300	10	89,177.16	891,771.6	267,531.48
2	GOSEPA	285	8	28,832.19	230,657.52	65,737.39

Source: Laboratory Analysis Adamu, 2019.

Table 9: Average Annual Waste Disposal at the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

Table 9: shows that the initial year when dumping of waste commences at INEX dumpsite was 2009 and as at 2018, 584,978 tons of waste have been deposited there with an average annual disposal of 64,997.56 tons per year, and the calculated year of the dumpsite closure is year 2034. While GOSEPA dumpsite has 2005 as its year of initial dumping of waste and 225,259 tons of waste have been deposited there as at 2018 with

an average annual disposal rate of 17,327.62 tons per year, and the calculated year of the dumpsite closure is year 2051.

Table 9: Average Annual Waste Disposal at the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

S/N	Dumpsites	IYWD	Waste at 2018(t)	Average AWD Tons/year	Calculated Year of Dumpsite Closure
1	INEX	2009	584,978	64,997.56	2034
2	GOSEPA	2005	225,259	17,327.62	2051

Source: Laboratory Analysis Adamu, 2019.

DISCUSSION OF RESULT

The result in Table 8 shows that the waste at INEX dumpsite has a density of 300Kg/M^3, the site has the calculated capacity of 891,771.6M^3 and current capacity of 267,531.48 in tons, while waste at GOSEPA dumpsite has a density of 285Kg/M^3, the site also has the calculated capacity of 230,657.52M^3 and current capacity 65,737.39 of the waste at the dumpsite in tons. While the result in Table 9 shows that the initial year when dumping of waste commenced at INEX dumpsite was 2009 and as at 2018, 584,978 tons of waste have been deposited there with an average annual disposal of 64,997.56 tons per year, and the calculated year of the dumpsite closure of 2034. While GOSEPA dumpsite has 2005 as its year of initial dumping of waste and 225,259 tons of waste have been deposited there as at 2018 with an average annual disposal rate of 17,327.62 tons per year, and the calculated year of the dumpsite closure of 2051. In view of the foregoing and with the result in the two tables (8 & 7) mentioned above, suggest that with the density and the large volume of waste at the two dumpsites whose expected date of closure are 2034 (INEX) and (2051) GOSEPA, and with high rate of urbanization (3.5%) and population growth rate of 3.2% per annum, Gombe metropolis stands the potential of generating more municipal solid waste that can be converted to energy (NPoP'C, 2009). Therefore, the result in Table 7 shows that the energy recovery potentials of the two dumpsites under study was found to have a total potential electricity generation of 439,577 kWh/day from both INEX (361,963.2kWh/day) and GOSEPA (77,613.8kWh/day) by burning

909.13kWh/tons of solid waste with INEX having (509.88kWh/tons) and GOSEPA (399.25kWh/tons), which translate into generating 18,315.7kW with INEX producing (15,081.8kW), and GOSEPA (3,233.9kW), based on the average household electricity consumption of 1,095kWh/year for Gombe metropolis (JEDCO, 2019), and assuming no energy lost, the total electricity generated could supply about 33,045.28 households with electricity daily, this corroborated a study by (Tester, 2015) which shows that the average energy generation per ton of municipal solid waste combusted in United States is about 563kWh/ton. Consequently, this indicates the feasibility of waste to energy plant in Gombe metropolis, and through the incineration of municipal solid waste generated there, substantial quantity of electricity can be produced.

CONCLUSION AND RECOMMENDATIONS

The analysis for the sustainability of renewable energy production from municipal solid waste generated in Gombe metropolis was carried around the two officially designated waste dumpsites (INEX and GOSEPA), and the following recommendations were drawn: The research therefore, recommend that government of Gombe State through the State ministry of Environment and Forest Resources should incorporate scavengers into the waste management stream, and also improve their surveillance mechanism to effectively regulate the activities of private waste management companies in order to harmonize the waste collection processes, transportation, treatment and disposal for the sustainability of the energy generation potentials from the incineration of the solid waste in Gombe metropolis, and the research further recommend another investigation to assess the economic sustainability of utilizing the solid waste generated in Gombe metropolis for energy generation.

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