Recycling Waste-to-Energy (WTE): Studies Carried-out in a Metropolitan City of the North-Eastern Nigeria

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Abstract
Studies on municipal solid waste (MSW) were carried-out in some selected locations from the Maiduguri metropolis. These wastes are produced and/or accumulated due to various human activities. Amongst the many factors that these wastes will course to the environment are: environmental degradation, insects, atmosphere (air) pollution, diseases, and disfigure the image of the city. In the effort to meeting the millennium development goals (MDGs) specification on environment, this paper is advocating that an appropriate solid waste management system/mechanism must be instituted. It is reasonable to recover energy from MSW through a variety of a process such as combustion pyrolysis and gasification. In this study, we estimated the energy content of the MSW from the Maiduguri metropolis in order to achieve its optimal system performances.
It was determined that the quantity of solid waste that are been deposited on daily bases at some selected/various locations were respectively 10,000kg/m^2, 20,000kg/m^2 , 40,000kg/m^2, 20,000kg/m^2 , 10,000kg/m^2 from Bagga road, Mairi ward, Monday Market, Post Office, and University of Maiduguri campus. These values determined were compared with the reported data from the literature, were energy values of different materials when incinerated to arrive at the corresponding energy (power) that can be produced from Maiduguri metropolis MSW.

Keywords: *MSW, MDGs, metropolis, environment, degradation.*

1.0 Introduction

Solid waste means any garbage, refuse, sludge from a waste water treatment or air pollution control facility and other discarded materials including solid, liquid semi-solid or contained gaseous material resulting from industrial, commercial, mining and agricultural operations, and from community activities, but does not include solid or dissolved materials in irrigation return flows or industrial discharges that are point source subject (Maduike, 1987).

The problem of solid waste and management is one of the most critical problems in Nigeria. A peculiar case is that of Maiduguri metropolis, where over the years MSW is gradually taken over of virtually every available open space in solid waste. Apart from physically obstructing legitimate human activities, the waste dumps have become fertile grounds for breeding mosquitoes, flies and other pests which have in effect constituted the dumps in to grave health hazard. These wastes, to say the least disfigure the city image and create an eyesore to the people (Maduike, 1987).
There is an obvious need to optimize the generation of waste and to reuse and recycle them, the technology waste to energy (WTE) or energy from waste is the process of creating energy

in the form of electricity or heat from the incineration of waste. Most (WTE) process produce electricity directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuel which could be used for both domestic and industrial applications.

One event that acted partly to create, or least that has worsened the waste problem in our urban centres is the rapid rate of population growth. Population is not the only affected solid waste by volumes but also made solid waste management strategies incapable of keeping pace with the rate of generation. The consequences to these effects have been disastrous. For example in Maiduguri cities the volume of solid wastes have assumed such alarming proportions that they have constituted blockages across streets and river channels rendering them inaccessible to traffic and water respectively. Indeed it has been opined that the re-occurring flood disaster in the city of Maiduguri and major cities in Nigeria which destroyed lives and properties worth millions of Naira was largely caused by solid waste which choked up channels of rivers and gutters within the city (Kagu, 1996). Waste generation rate in Maiduguri, are affected by socio economic development, degree of industrialization, and climate.

The composition of solid waste in an urban/metropolitan city is described as follows: 51% - municipal solid waste, 38% - agriculture and 11% - industry.
Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced. Reduction in the volume and mass of solid waste is a crucial issue especially in the light of limited availability of final disposal site in many part of the world. Although numerous waste and by product recovery process have been introduced, anaerobic digestion has unique and integrative potentials, simultaneously acting as a waste treatment and recovery process (Maduike, 1987).
This paper presents the possible solution to MSW and harnessing the waste-to-energy, WTE, the studies were carried out at some selected location in Maiduguri metropolis on daily basis. The limitation of the study is to compare the determine quantity of wastes with the standard wastes figures from the literature data.

1.1 Effects of Solid Waste on Environment

It has been recognized that improper disposal of solid waste has a lot of health hazards and other negative consequences on the people and the environment. Open waste dumps in most areas have become breeding grounds for mosquitoes, flies, rats and other diseases. Some of the major effects of solid waste include the following; Environmental; degradation, insects atmospheric pollution, odour (Oduola, 1986).

1.1.1 Environmental Degradation

Large heaps of waste and the indiscriminate manners in which people dump them have become eyesore to members of the public. It destroys the scenery of the environment. It also becomes a source of psychological disorder. Unclear waste lowers the aesthetic quality of the locality and property values in the affected neighborhood (Oduola, 1986).

1.1.2 Insects

The transmission route of filth induced diseases such as malaria; cough, cholera, dysentery, diarrhea; vomiting and a host of others are largely brought about by insect such as flies, mosquitoes and other insects that use the dumps as their breeding grounds. These diseases are the commonest in almost every urban centre in Nigeria (Oduola, 1986).

1.1.3 Atmospheric Pollution

When waste is burn in the open place, a pool of dense black smoke often covers the site and in neighboring land so that its positions can be located from a distance. Apart from the particular matter that constitutes smoke, gases discharges from incomplete oxide and various other noxious oxide which are dangerous to human health, pollution of water resources is also another inherent character of waste disposal in open areas (Oduola, 1986).

1.1.4 Odour

The waste-constitutes a source of stench and offensive odour to the human being and the environment. These arise as a result of combination of rotten vegetables and other solid wastes that are indiscriminately discarded and when this situation persists all day and all night for a reasonable period of time. It constitutes a major environmental nuisance. Passerby and indeed people living around such environments find this odour uncomforted and un-attraction (Oduola, 1986)

1.2 Method of Municipal Solid Waste Disposal

The municipal solid waste industry has four components: recycling, composing, land filling, and waste to energy.

1.2.1 Recycling

Recycling is a process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new product. Recycling can benefit your community and the environment (Oyinlola, 2001).

1.2.2 Benefits of Recycling

Reduce the amount of waste sent to landfills and incinerators, conserves natural resources such as timber waste and minerals, prevents pollution caused by reducing the need to collect new raw materials, saves energy, reduce greenhouse gas emission that contribute to global climate change. Helps sustain the environment for future generations; help create new well-paying jobs in the recycling (Oyinlola, 2001). In these methods, efficient recovery of wastes like glass, plastics, metals and cans can be achieved by the separation of the recyclables in Maiduguri (Kagu, 1996). It was observed that plastic waste materials are turned into plastics in the Maiduguri based Mandau plastic company. However, an expert in plastic recycling indicated that there are over 30 different types of plastic in use and it is difficult to differentiate one from the other. A mixture of these therefore produce a products which is brittle (not durable) and has limited useful properties (Kagu, 1996).

1.2.3 Composting

Composting organic materials such as yard trimming, foods scraps, woods waste and paper are helps to manage the largest compound of our trash the garbage waste we dispose of making up more than two-thirds of the solid waste disposal streams. The amount of yard waste and its municipal solid waste disposal market share have declined dramatically in the last four decades which the composting rate has sod red. Backyard compost piles and grass cycling programmed have helped to reduce yard waste generation composting services as and environmentally friendly waste disposal solution by cutting town on the amount of garbage waste headed to landfills. State and local composting requirement have increased the number of commercial composting operation, composting which involves the controlled decomposition of plant remains and other organic materials to male an earthy, dark, crumbly substance that is excellent for enriching soil and preventing soil erosion is a part way to recycle yard and kitchen wastes and reduce the volume of garbage waste sent to landfills or incinerators for disposal (Welsh Assembly, 2005).

1.2.4 Land Filling

Modern landfills are well engineered facilities that are located, designed operated and monitored to ensure compliance with federal regulations. Solid waste landfills must be designed to protect the environment from contaminated which may be present in the solid waste stream. The land fill siting plan which prevents the siting of landfills in environmentally sensitive areas as well as on site environmental monitoring systems which monitor for any sign of ground water contamination and for landfill gas provides additional safeguards. In addition, many new landfills collect potentially harmful land fill gas emission and convert the gas in to energy.

The U.S. environmental protection Agency's landfill methane outreach programmed (LMOP) is a voluntary assistance programme that helps to reduce methane emission from landfill by encouraging the recovery and beneficial use of landfill gas (LFG) as an energy resource. LFG contain methane, a potent greenhouse gas that can be captured and used to fuel power plants, manufacturing facilities vehicles home and more by joining LMOP, companies, state agencies, organization, landfills and communities gain access to a vast network of industry experts and practitioners, as well as to various technical and marketing resources that can help with Landfill Gas LFG energy project development (EPA, 1996 US).

1.2.5 Methane Emission from Landfill

Municipal solid waste (MSW) landfills are the third largest sources of human related methane emissions in the United States, accounting for approximately 17% of these emissions in 2009. At the same times, methane emission from landfills represents a lost opportunity to capture- and use a significant energy resource. LFG is created as solid waste decomposes in a landfill. This gas consist of about 50 percent methane (the primary component of natural gas), about 50 percent carbon dioxide Co_2 and a small amount of non-methane organic compounds.

1.2.6 Converting Landfills Gas to Energy (LGE)

Instead of escaping in the air, Landfill Gas (LFG) can be captured converting a used as an energy source. Using Landfill Gas (LFG) helps to reduce odours and other hazards associated with landfill Gas (LFG) emissions and it helps prevent methane from migrating in to the atmosphere and contributing to local smoke and global climate change.

LFG extracted from landfills using a series of wells and a blower/flare (or Vacuum) system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use for the gas. From this point, the gas can be flared, used to generate electricity, replace fossil fuel in industrial and manufacturing operation, or upgraded to pipeline quality gas where the gas may be used directly or processed in to an alternative vehicle fuel (EPA, 1996 US).

2.0 Background on Waste-to-Energy, WTE

This is the energy recovery from waste in the conversion of non-recyclable waste materials in to usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion and landfill gas (LFG) recovery (Herbert, 2007).

Energy recovery from waste is part of the nonhazardous waste management hierarchy. Converting non-recyclable waste materials into electricity or heat generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills. Currently there are 86 facilities in the united stated for combustion of municipal solid waste (MSW) with energy recovery. These facilities are located in 25 States mainly in the Northeast. No new plants have been built in the US since 1995, but some plants have expanded to handle additional waste and create more energy. The 86 facilities have the capacity to produce 2,720 MW of power per year by processing more than 28 million tons of waste in the US. In 2010, combustion of about 29 million tons of MSW (≈ 12 %) for approximately ten percent of the volume remains ash. This ash is generally sent to a landfill (Shi-Ling, 1999).

Waste to energy incinerate is the fourth aspect of the EPA's approach to solid waste management. It is the controlled burning of solid waste at extremely high temperature often as high as 2000^o F. incineration of all types currently accounts for 14% of solid waste disposal in the U.S. The EPA estimates that 23% of the municipal solid waste stream will be disposed of visa incineration by 1995. WTE incineration is widely used in Japan, some part of Europe, and elsewhere to reduce by as much 80 to 90% the volume of waste that must be land filled. Waste to energy incineration should not be confused with simple open burning of refuse. It is even different from mass bur waste incineration common in the U.S. in the first half of the 20th century. In waste to energy incineration, the heat generated by the process is captured and turned in to useable energy. The energy affiliated organization and contacts industrial classification, and linkages to environmental permit and programmed (Shi-Ling Hsu, ed., 1999).

2.1 Waste-to- Energy Conversion Path Ways
There are three main path ways for conversion of organic waste material to energy:

2.2 Thermo chemical - Thermo Chemical Conversion: - Characterized by higher temperature and conversion rates, is best suited for lower moisture feedstock and is generally less selective for products. Thermo chemical conversion include; incineration, pyrolysis, and gasification
The incineration technology is the controlled combustion of waste with the recovery of heat to produce steam which in turn produces power through steam turbines.
Pyrolysis and gasification represent refined thermal treatment method as alternative to incineration and are characterized by the transformation of the waste in to product gas as energy carrier for later combustion in for example a boiler or a gas engine (Rosenthal and Elisabeth, 2010).

2.3 The Biochemical Conversion: - Process which include anaerobic digestion and fermentation, are preferred for wastes having high percentage of organic biodegradable (putrescible) matter and high moisture content. Anaerobic digestion can be used to recover both nutrient and energy contained in organic waste such as animal manure. The process generates gases with a high content of methane (55 – 70%) as well as bio-fertilizer. Alcohol fermentation is the transformation of organic fraction of waste to ethanol by a series of biochemical reaction using specialized microorganisms (Rosenthal and Elisabeth, 2010).

2.4 The Physiochemical: - Technology involves various processes to improve physical and chemical properties of solid waste. The combustible fraction of the waste is converted into high energy fuel pellets which may be used in steam generation. (Rosenthal, Elisabeth, 2010). Full pellets have several distinction advantages over coal and because it is cleaner, free from incombustible, has lower ash and moisture contents of uniform size, is cost-effective, and eco-friendly (Rosenthal and Elisabeth, 2010).

2.5 Factors Affecting Energy Recovery

The two main factors which determine the potential of recovery of energy from wastes are the quantity and quality (Physico-chemical characteristics) of the waste. Some of the important physiochemical parameters requiring consideration include, Size of constituents, density, moisture content, volatile solid/ organic matter, fixed carbon, total inert, calorific value often, can analysis of waste to determine the proportion of carbon, hydrogen oxygen, nitrogen, and sulphur (ultimate analysis) I done to make mass balance calculation for both thermo chemical and biochemical processes. In case of anaerobic digestion, the parameters C/N ratio (a measure of nutrient concentration available for bacteria growth) and toxicity representing the presence of hazardous material which inhibit bacteria growth also require consideration) (Rosenthal and Elisabeth, 2010).

2.6 Significance of Waste to Energy (WTE) Plant

While some still confuse modern waste to energy plants with incineration of the past, the environmental performance of the industry is beyond reproach. Studies have shown that communities that employ waste to energy technology have higher recycling rates than communities that do not utilize waste to energy. The recovery of ferrous and non-ferrous metal from waste to energy plants for recycling is strong and growing each year. In addition numerous studies have determines that waste to energy plants actually reduce the amount of greenhouse gases that enter the atmosphere (Rosenthal, Elisabeth, 2010).

Now a day, waste to energy plants based on combustion techniques are highly efficient power plant that utilize municipal solid waste as their fuel rather than coal, oil or natural gas. For better than expending energy to explore, recover, process and transport the fuel from some distance source, waste to energy plant find value in what other consider garbage. Waste to energy plant recover the thermal energy contained in the trash in highly efficient boilers that generate steam that can then be sold directly to industrial customers or used on-site to drive turbine for electricity production. WTE plants are highly efficient in harnessing the untapped energy potential of organic waste by converting the biodegradable fraction of the waste in to high calorific value gases like methane. The digested portion of the waste is highly rich in nutrients and is widely used as bio-fertilizer in many part of the world (Themelis, Nickolas J. 2003)

2.6 Waste – to – Energy around the World

To an even greater extent than in the United States, waste to energy has thrived in Europe and Asia as the prominent method of waste disposal. Landing waste to energy for its ability to reduce greenhouse gas emission European nation rely on waste to energy as the European Union has issued as legally binding requirement for its member States to limit the land filling of biodegradable waste (Tangri and Neil, 2003).

The confederation of European waste to energy plant (CEWEP) notes that Europe currently treats 50 million tons of waste at waste to energy plants each year, generating an amount of energy that can supply electricity for 27 million people or heat for 13 million people. Upcoming changes to EU legislation will have a profound impact on how much further the technology will help achieve environmental protection goals describing the advances of waste to energy, the German ministry for the environment cities drastic reductions in emission of dioxin, dust and mercury. Twenty years ago, is Swedish waste to energy plant emitted total of about 100grams of dioxin every year. Today the collective dioxin emission from all 29 Swedish waste to energy plants amount of 0.7 of a gram. It is clear that Europe has made similar strides as the United States with respect to emission reduction (Tangri, Neil, 2003).

2.7 Combustion with Energy Recovery

2.7.1 Types of MSW Combustion Technologies.

There are three types of technology for the combustion of municipal solid waste.

2.7.2 Mass Burn Facilities:-

Burn facilities are by far the most common types of combustion facilities in the United State. The wastes used to fuel the mass burn facility may or may not be sorted before it enters the combustion chamber. Many advanced municipalities separate the waste on the front end to pull off as many recyclable products as possible. Mass burn units are designed to burn municipal solid waste in a single combustion chamber under condition of excess air. In combustion system, excess air must be used to promote mixing and turbulence to ensure that air can reach all ports of the waste. This is necessary because of their consistent nature of solid waste. Most mass burn facilities burn municipal solid waste on a sloping, moving grate thus vibrated or otherwise moved to agitate the waste and mix it with air.

2.7.3 Modular System

Modular systems are designed to burn up processed mixed MSW they differ from mass burn facilities that they are much smaller and are portable. They can be moved from site to site.

2.7.4 Refuse Derived Fuel System:-

These facilities used mechanical methods to shred incoming municipal solid waste separate out non-combustible materials, and produce a combustible mixture suitable as a fuel in a dedicated furnace or as a supplemental fuel in a conventional boiler system.
At a municipal solid waste combustion facility MSW is unloaded from collection trucks and placed in a trash storage bunker. An overhead crane is used to sort the waste and then life it in to a combustion chamber to be burned. The heat released from burning is used to convert water to steam (Michaels and Ted, 2009).

The steam is then sent to a turbine generator to produce electricity. The remaining ash is collected and taken to a land fill. Particulate are capture by a high efficiency bag house (a filtering system). As the gas stream travels through the filters, more than 99 percent of particulate matter is removed. (Captured fly ash particles fall in to hoppers funnel shaped receptacles) and are transported by an enclosed conveyor system to the ash discharger where they are wetted to prevent dust and mixed with the bottom from the grate. The ash residue is the conveyed to an enclosed building where it is loaded in to covered leak proof trucks and taken to a land water contamination. Ash residue from the furnace can be processed for removal of recyclable scrap metals.

Figure 2.1: WTE Control room of a typical moving grate incinerator overseeing two boiler lines **Sources: Themelis, Nickolas, (2003).**

Figure 2.2: Municipal solid wastes in the furnace of a moving grate incinerator capable of handling 15 metric tons (17 short tons) of waste per hour. The holes in the grate elements supplying the primary combustion air are visible. **Source: Themelis, Nickolas, (2003)**

Figure 2.6: Operation of an incinerator aboard an aircraft carrier,
Source: Themelis, Nickolas, (2003)

2.8 Ash Generated From the MSW Combustion Process

The amount of ash generated ranges from 15-25 percent by weight of the MSW processed and from 5 – 15 percent of the volume of the MSW processed. Generally, MSW combustion residues consist of two types of material. Fly ash and bottom; Fly ash refers to the fine particles that are residue from other air pollution control devices such as scrubbers. Fly ash typically amount to 10-20 percent by weight of the total ash (Themelis and Nickolas, 2003)

The rest of the MSW combustion ash is called bottom ash (80-90 percent by weight). The main chemical components of bottom ash are silica (sand and quality) calcium iron oxide and aluminum oxide. Bottom ash usually has a moisture content of 22-62 percent by dry weight. The chemical composition of the ash varies depending on the original MSW feedstock and the combustion process. The ash that remains from the MSW combustion process is sent to land fill (Themelis and Nickolas, 2003).

Table 2.1: Energy values of different materials when incinerated

S/No	Materials	BTU per pound
1.	Plastics	11.00 – 20,000
2.	Rubber	10,900
3.	Newspaper	8,000
4.	Corrugated Boxes (paper)	7,000
5.	Yard wastes	3,000
6.	Food wastes	2,600
7.	Average of MSW	4,500 – 4,800

Sources: (Michaels, Ted, 2009)

3.0 Research Methodology

In this study, a careful assessment and quantitative determination of all wastes deposited at some 5-selected locations in the metropolis are namely as follows: Bagga road, Mairi ward, Monday Market, Post Office, Unimaid.

Qualitatively determine the relative weight by the area of each kind of material deposited at the locations on daily basis, such as plastics, rubber, newspapers, corrugated boxes (paper), yard wastes, food wastes at various interval of days as follows, Monday 25 March 2013, Wednesday 27 March 2013, Tuesday 2 April 2013, Friday 5 April 2013, Saturday 7 April

2013, Wednesday 10 April 2013, Friday 12 April 2013.

The determined quantities of all wastes deposited on daily basis in the above locations were then compared with the standard data from the literature. The results help us to know the amount of energy (in terms of power) that can be produce from these wastes.

(a) 25th March 2013

(b) 27th March 2013

Figure 3.1: Picture of combine waste materials at Bagga road.

Figure 3.2: Picture of combine waste materials at Bagga road location on 2nd April, 2013

(b) 25th March 2013

(b) 27th March 2013

Figure 3.3: Picture of combine waste materials at Mairi ward

Figure 3.4: Picture of combine waste materials at Mari Ward location on 2nd April, 2013

(a) 25th March 2013 (b) 27th March 2013

Figure 3.5: Picture of combine waste materials at Unimaid.

Figure 3.6: Picture of combine waste materials at Unimaid location on 2nd April, 2013


(c) 25th March 2013 (b) 27th March 2013

Figure 3.7: Picture of combine waste materials at Monday market

Figure 3.8: Picture of combine waste materials at Monday Market location on 2nd April, 2013


(a) 25th March 2013 (b) 27th March 2013

Figure 3.9: Picture of combine waste materials at Post office.

Figure 3.10: Picture of combine waste materials at Post Office location on 2nd April, 2013

4.0 Discussions of the Results

The results obtained in this study are presented as follows:

Table 4.1: Bagga road with location area size of 20m^2

Waste assessment date	Material composition (kg/m^2) Plastics	Rubber	Newspapers	Corrugate boxes paper	Yard wastes	Food wastes
25/03/2013	700	70	560	420	490	630
27/03/2013	1050	105	700	700	630	700
02/04/2013	2100	175	840	1400	770	1050
05/04/2013	2800	350	1050	1750	1050	1400
07/04/2013	3500	420	1400	2800	1190	2100
10/04/2013	4200	455	2800	3500	1330	2800
12/04/2013	6650	525	3150	4830	2540	5320
Total average	3000	300	1500	2200	1000	2000

Table 4.2 Amount of Solid Wastes Produce on Daily Basis at Bagga Road Locations

S/No	Materials	Measured weights (Kg)
1,	Plastics	3000
2.	Rubber	300
3.	Newspaper	1500
4.	Corrugated boxes (paper)	2200
5.	Yard wastes	1000
6.	Food wastes	2000
	Total	10,000

Table 4.3 Mairi Ward with location Area of 30m²

Waste assessment date	Material composition (kg/m²) Plastics	Rubber	Newspapers	Corrugate boxes paper	Yard wastes	Food wastes
25/03/2013	2100	210	350	630	1400	700
27/03/2013	3500	350	1400	700	2100	1400
02/04/2013	4200	420	2450	1050	2800	2100
05/04/2013	6300	700	2800	1400	3500	2800
07/04/2013	8400	1400	3500	2100	4900	3500
10/04/2013	10500	1820	4200	2800	5600	4200
12/04/2013	14000	2100	6300	5320	7700	6300
Total average	7000	1000	3000	2000	4000	3000

Table 4.4 Amount of Solid Wastes Produce on Daily Basis at Mairi wards Locations

S/No	Materials	Measured weights (Kg)
1,	Plastics	7000
2.	Rubber	1000
3.	Newspaper	3000
4.	Corrugated boxes (paper)	2000
5.	Yard wastes	4000
6.	Food wastes	3000
	Total	20,000

Table 4.5: Monday market location with Area of 40m²

Waste assessment date	Material composition (kg/m²) Plastics	Rubber	Newspapers	Corrugate boxes paper	Yard wastes	Food wastes
25/03/2013	5600	700	2100	700	2800	2100
27/03/2013	7000	1400	3500	2100	4200	3500
02/04/2013	8400	2100	4200	3500	6300	5600
05/04/2013	9100	2800	4550	4200	9100	8400
07/04/2013	11200	3500	7000	6300	9800	10500
10/04/2013	14000	4200	8400	8400	10500	11900
12/04/2013	14700	6300	12,250	9800	13300	14,000
Total average	10,000	3000	6000	5000	8000	8000

Table 4.6: Amount of Solid Wastes Produce on Daily Basis at Monday market Locations

S/No	Materials	Measured weights (Kg)
1,	Plastics	10,000
2.	Rubber	3,000
3.	Newspaper	6000
4.	Corrugated boxes (paper)	5000
5.	Yard wastes	8000
6.	Food wastes	8000
	Total	40,000

Table 4.7: Post Office location with Area of 30m^2

Waste assessment date	Material composition (kg/m^2) Plastics	Rubber	Newspapers	Corrugate boxes paper	Yard wastes	Food wastes
25/03/2013	1400	140	560	490	700	1050
27/03/2013	3500	175	840	630	2100	1400
02/04/2013	4900	280	1190	770	3500	2800
05/04/2013	5600	350	1750	1050	4200	4900
07/04/2013	7000	490	2800	1190	6300	5600
10/04/2013	9100	700	4200	1330	8400	8400
12/04/2013	10500	1365	6160	1540	9800	10850
Total average	6000	500	2500	1000	5000	5000

Table 4.8: Amount of Solid Wastes Produce on Daily Basis at Post Office Locations

S/No	Materials	Measured weights (Kg)
1,	Plastics	6000
2.	Rubber	500
3.	Newspaper	2500
4.	Corrugated boxes (paper)	1000
5.	Yard wastes	5000
6.	Food wastes	5000
	Total	20,000

Table 4.9: Unimaid location with Area of 20m^2

Waste assessment date	Material composition (kg/m^2) Plastics	Rubber	Newspapers	Corrugate boxes paper	Yard wastes	Food wastes
25/03/2013	700	70	490	350	2800	2100
27/03/2013	1400	84	630	420	4200	3500
02/04/2013	2800	112	770	630	6300	5600
05/04/2013	4200	154	1050	700	9100	8400
07/04/2013	5600	224	1190	770	9800	10500
10/04/2013	6300	280	1330	1330	10,500	11,900
12/04/2013	7000	476	1540	1400	13300	14000
Total average	4000	200	1000	800	3000	1000

Table 4.10: Amount of Solid Wastes Produce on Daily Basis at Unimaid Locations

S/No	Materials	Measured weights (Kg)
1,	Plastics	4000
2.	Rubber	200
3.	Newspaper	1000
4.	Corrugated boxes (paper)	8000
5.	Yard wastes	3000
6.	Food wastes	2000
	Total	10,0000

Table 4.11: Combined Solid Wastes Data weight of each material at selected locations

S/No	Materials	Weights in Kg
1.	Plastics	30000
2.	Rubber	14000
3.	Newspaper	11000
4.	Corrugated boxes (paper)	21000
5.	Yard wastes	19000
6.	Food wastes	5000

Table 4.12: Standard data used from literature: The energy values of different materials when incinerated

S/No	Materials	BTU per pound
1.	Plastics	11,000-20,000
2.	Rubber	10,900
3.	Newspaper	8,000
4.	Corrugated boxes (paper)	7,000
5.	Yard wastes	3,000
6.	Food wastes	2600
7.	Average for MSW	4500-4800

Source: Energy recovery council (2009)

Table 4.13 depicts the comparison of Table 4.11 and Table 4.12 to arrive at the energy produced by combined waste materials when incinerated.

Table 4.13: Energy derived from the Comparison of Table 4.11 with 4.12

S/No	Materials	kJ Per kg
1.	Plastics	490575000
2.	Rubber	57497500
3.	Newspaper	118160000
4.	Corrugated boxes (paper)	81235000
5.	Yard wastes	66465000
6.	Food wastes	52117000
	Total	866049500

The energy conversions were carried out as depicted below:

3600 KJ	1 KWh
866049500KJ	

= 240,569. 3056 KWh

5.0 Conclusions

The waste-to-energy (WTE) plants offer two important benefits of environmentally safe waste management and disposal, as well as the generation of clean electric power. WTE facilities produce clean renewable energy through thermo-chemical, biochemical and physiochemical methods. The growing use of WTE as a method of dispose-off solid, liquid wastes and generates power has greatly reduced environmentally impacts of municipal solid waste (MSW). Based on the quantities of MSW produced yearly, their recycle can satisfactorily be used to produce energy that can add immense values (i.e. 240,569. 3056 KWh) to the national power generation, from Maiduguri metropolis alone. WTE can play a vital role in mitigating the problems of disfiguring the city's image and an eyesore to the people.

Recommendations

1. The three tiers of government should introduce this technology of WTE as the best way of MSW management and disposal. Because this project go hand in hand with community and corporate body to cleaner air (healthy living), renewable energy, and economic development which helps to improve public welfare, safety and reduction in green house (global warning) gases. In addition, it increases environment protection, better waste management and responsible community planning.
2. When these WTE technologies is fully instituted in the Nigeria, the collections of waste should be commercialized at every domestic, industrial etc., this will encourage household to manage their waste for disposal properly.
3. Government should, if it has not already done so, enact a law to take care of defaulters of laid down guideline for sanitation. For instance people should be held responsible for their irresponsible waste disposition, either in residential and/or workplace. There should be sanitation inspectors to report cases to law enforcement agencies when the people appear indifferent to the quality of their immediate environment.

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