Converting Urban Solid Waste to Energy in Enugu Urban Area, Southeast, Nigeria

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Abstract

The increase in population, rapid rate of urbanization and the upsurge in economic activities in Enugu urban area have produced severe problems in many aspects, among which are solid waste management and energy insufficiency. Notwithstanding the emergence of distinct waste and energy linkage, the concept of "waste to energy" yet is viewed as substandard method in Nigeria. The Nigerian government and also other interested stakeholders concentrate their attention more on hydropower, the chief source of electricity generation in Nigeria. This study aims at linking solid waste management and insufficient energy supply. It makes use of journal articles, data from National population commission and Enugu Electricity Distribution Company. Descriptive statistics is used to present the findings of the study. Enugu urban generates about 420 tons/day solid waste from its six waste management zones. The study has shown some opportunities for Enugu urban area to convert its solid waste into energy. Even if only organic waste is treated, it generates energy sufficient to light more than 900 houses in Enugu urban area. The quantity of waste, its heat content, the need of additional energy supply, the support from government and service users are some openings that hopefully can contribute to resolving the problems of solid waste and energy supply in Enugu urban area.

Key words: *Urban Solid waste, Composition, Energy value, Electricity,*

INTRODUCTION

The problems of waste management in all districts in Enugu urban area have continued to worry relevant government authorities. The constantly increasing geographical extension of the city together with its geometrical progression in population, rapid rate of urbanization, changing peoples' life styles and rise of economic activities have impact adversely on sanitation and health, good source of water for consumption, management of waste, impromptu housing projects and energy source (Shrestha, sartohadi, Ridwan & Hizbaron, 2014). Solid waste is defined as the collection of garbage materials originating from activities of human and animal that are rejected as useless and unwanted. Solid waste is produced from residential, industrial and commercial activities in an area, and it has various ways of handling.
The Enugu municipality which consists empirically of about six waste management zones (New Haven, Abakpa, Agbani road, Coal Camp (Ogbete), Emene and Ogui) generates 420 metric tons

of solid waste per day at the rate of 0.48kg per capita per day (Nwoke *et al.,* 2020). This massive amount of solid waste has been generating disposal and treatment problems. The life of Enugu urban people have been affected by severe environmental problems. Whereas people are facing the problems, the solid waste management remains a huge question mark. Enugu waste disposal authorities have been doing their best but then a lot more has to be done. The accumulations of solid waste can be seen all over the places, along road sides, beside water channels, near markets and many other city corners.

Further on, as point out earlier, the rise in population also has affected the energy supply (electricity) in Enugu urban area. This paper aims at drawing a connection between two main problems standing out in Enugu urban area: the solid waste management and insufficient energy supply to the urban occupants.

Research Problems:

Recently, there have been massive increase in the population of Enugu urban dwellers, and this increment necessitates an expansion of residential layout to accommodate such population. Consequent upon such massive population increase are continuous generation of solid waste which pose environmental issues, and inefficient power supply. As waste generated is toxic to the environment which negatively affect man, it can also through adequate process be converted to energy. This will assist in mitigating the effects of both solid waste generation and inefficient power supply to Enugu urban dwellers.

Aims and Objectives:

The main aim of the study is to carry out investigation on the connection between two main problems standing out in Enugu urban area: the municipal solid waste management and insufficient energy supply to the urban occupants.

Specifically, the study seeks to:

i. To determine the physical composition of Enugu urban solid waste (EUSW).
ii. To determine the energy content of Enugu urban solid waste (EUSW).

LITERATURE REVIEW

This study makes use primarily of literature survey and secondary data for discussion and analysis. National population reports, National Bureau of Statistics, Enugu Electricity Distribution Authority are some of the sources for obtaining the data to be used in this study.

Urban Areas Solid Waste Management (SWM) System

In several developing countries of the world solid waste management has always been a main issue. For instance, Greece, was using landfill and open dump solid waste management techniques which lasted till late 1980s (Shrestha *et al.,* 2014). The lack of systematic facilities, coordination and governance of the concerned institutions has created serious problems in the solid waste disposal (Boemi, Papadopoulos, Karagiannidis, and Kontogianni, 2010). However, later, the legislation and environmental planning of Greece has set the target to implement internal SWM, followed by the ongoing reduction of biodegradable solid waste which is presently steering to landfilling, increasing recycle activities and also the closure of open dumping sites (Boemi, Papadopoulos, Karagiannidis, and Kontogianni, 2010). One of the recently proposed ways of waste management is to recover the energy from the waste through high temperature thermal treatment, as waste contains significant amount of biodegradable matters, that is expected be used as renewable energy source (Rentizelas, Tolis, and Tatsiopoulos, 2014).

India is an example of a fast growing country. Rapid growth of industrialization, population and urbanization has caused huge amount of municipal solid waste that lead to environmental degradation (Singh, Tyagi, Allen, Ibrahim, and Kothari, 2011). Unfortunately, most of the cities there are not able to cope up with environmental pressure due to lack of facilities. With waste generation per capita of 0.5 kg/day, India is facing a major challenge in municipality solid waste management (Kalyani, and Pandey, 2014). Sharholy *et al*. (2008) has conducted rigorous review on solid waste management in Indian context. Mindsets are changing with the progress of development and education. The price hike in petroleum products and other power have enforced the concerned institutions and investors to make energy recovery projects from waste become more practical (Sharholy cited in (Kumar, and Goel, (2009)). In response to Kyoto Protocol and agreement in Marrakech, Korea has been giving serious attention on CO_2 emission reduction. The development of renewable energy is considered as one way to reduce CO_2 emission and socio-economic cost due to environmental pressure. As one of the possible sources of energy alternative, the government has been promoting the expansion of landfill gas for electricity generation. Shin, Park, Kim, and Shin, 2005) had conducted economic and environmental analysis to see the prospect of landfill gas to generate electricity, under various scenarios of technology. The result showed that electricity generation from waste using steam turbine was the most economical way. However, there are still uncertainties in utilizing landfill gas and the introduction of it to energy market. The technology, economy and regulations are few to take into account in promoting waste to energy concept in Korea (Shin *et al*., 2005).

Indonesia is the countries in fourth position in the world in its population (UNFPA World Population 2012). Gunnamatta has perceived that solid waste management solution is not a straight forward problem. The collection and disposal are not the final answer. Different types of methods are available, but the characteristic of waste which is not homogeneous, has created other hindrances. The life cycle assessment on various ways to recover the energy from solid waste in Yogyakarta province has been conducted to encounter questions such as: anaerobic digestion or landfill, thermal conversion or landfill, loss or benefit to the environment (Gunamantha, 2012). The study showed that direct gasification was supposed to be the safest method in energy recovery from solid waste. Life cycle assessment was considered the appropriate technique to evaluate diverse waste treatment methods in relation to their environmental impact.

In Nigeria, most dumpsites are not managed and engineered properly (Ogwueleka, 2009), and eventually pollutants discharged from the dumpsites have serious impact on human lives either indirectly or directly (Zahari et al, 2010; Nwoke et al., 2020). According to Onyia, et al (2019) solid wastes, constantly collected from urban areas, have in recent times thought as an important renewable source of energy. Generating energy from urban solid waste is achievable by applying energy generation technologies as incineration, Liquefaction, combustion, gasification and pyrolysis (Onyia et al., 2020)

The operational design of the aforementioned energy generation technologies centered on urban solid waste are greatly connected to energy value of the used urban solid waste materials. Therefore, determining energy value of urban solid waste is a vital operation to performing the effective operational design of the waste to energy conversion (WTE) technologies (Kalantarifard and Yang, 2011; Nwoke et al, 2020 C).

Many people have conducted many research in urban waste management in Enugu urban but have not considered more about method of sustainable waste management. As a result much ecological damage continues to rise. Therefore, this study aims at presenting an investigation on converting the Enugu urban waste to energy. This will assist in reducing the waste management issues and sustainably protect our eco-system.

Waste to Energy Concept

The process of converting waste into electricity or gas is known as Waste to energy (WTE). The wastes are mainly generated from residence areas, industrial activities, commercial activities and institutional activities (offices). The word "waste" denotes an unwanted by-product of a manufacturing process, chemical laboratory, or nuclear reactor. Historically, the first incineration plant was built in Denmark in 1903 (Habib, Schmidt, and Christensen, 2013). As the consumption of energy continues to rise, the idea of converting solid waste to energy becomes an important issues in encouraging an alternate energy source. The need for environmental pressure reduction and efficient energy source for quality life have generated a firm connection between energy and waste (Habib, Schmidt, and Christensen, 2013). In most waste management programs, reusing and recycling are the utmost preferred techniques. However, waste conversion to energy is seen as a significant aspect in the management of solid waste.

Burning of solid waste was previously a process of both shrinking solid waste volume and reduction of its detrimental effect to human (Shrestha et al., 2014). Today, there is an integration of waste incineration and energy extraction (Bosmans, Vanderreydt, Geysen and Helsen, 2013).

There are various technological processes of converting solid waste into energy. The most common technology as identified by (Kalyani, and Pandey, 2014) are thermal conversion, landfilling and biochemical conversion (Shrestha et al., 2014). Techniques for thermal conversion comprise pyrolysis, incineration (combustion), gasification and refuse derived fuel (RDF). The incineration otherwise known as combustion entails burning plastics, textile and organic waste. The heat generated from this technique is transformed into electricity. The release of poisonous gases as the negative effect of this process is the chief disadvantage of thermal conversion.

Biochemical process is a better alternative because is more eco-friendly. It is made up of composting, anaerobic digestion and vermicomposting. The technique of thermal conversion process encompasses trans-esterification as well as other processes that convert bio- oil and plants into biodiesel (Annepu cited in (Kalyani, and Pandey, 2014)); (Singh et al., 2011).

Landfilling, which is the commonest method of waste disposal in developing and least developed countries, has a simple technique of solid waste disposal in an open field. This process is easy but not eco-friendly and as a result cannot be taken as a suitable option.

The Energy Situation and the position of waste to Energy concept in Nigeria

Nigeria's electricity distribution network comprised of high voltage (19,226 Km of 11KV and 23,753 km of 33KV) networks from primary and sub-primary substations. The substations fed with their respective ratings are shown in table 1.

Table 1. **Nigeria Electricity substations fed with the ratings.**

Substations		
679	20,543	
Ratings		
33/11 kV	33/0.415KV ;	11/0.415KV

Source: (Nwoke *et al*., 2020)

Additional, injection and distribution transformers are 680 and 1,790 respectively. The transmission system has a wheeling capacity which is less than 4,000MW, and is overloaded. Some of the networks especially in the northern part experience poor voltage pattern. This is because of high prevalent rate of insufficient dispatch and control structure, radial and delicate grid network, recurrent collapse in the system and exceptionally high losses in the transmission. Electricity access is very poor in Nigeria. Estimate of 60 -70% Nigeria population live without access to electricity (Nwoke *et al*., 2020). Per capita electricity consumption is roughly 145 kWh in contrast to 4,198 kWh, 3,927kWh, 2,620kWh, and 351 kWh in South Africa, China, Brazil and Ghana, respectively (world bank group, 2021).

There are a lot of many renewable energy sources in Nigeria that need to be explored further but most stakeholders are particular about hydropower development which its capacity does not measure up with the electricity demand of the teeming population. Renewable energy will be considered as instant solution to energy crisis that has been a lasting feature in peoples' lives, particularly in urban areas.

Research Gap.

Unfortunately, many people have conducted many research in urban waste management in Enugu urban but have not considered more about method of sustainable waste management. As a result much ecological damage continues to rise. Thus this study is undertaken to close the gap.

METHOD OF RESEARCH

Area of study

Enugu urban area is roughly located between Latitudes 06˚30'N and 06˚40'N and Longitudes 07˚20'E and 07˚35'E. The urban area covers three local government areas and nine principal districts, some of them are Trans-Ekulu, Uwani, Coal Camp (Ogbete), Achala layout, New heaven, Ogui, Figure 1. According to (National Population Commission 2006) the population of the town was 772,664 in 2006 while its 2014 population was projected to 910,003 using the authorized 3% growth rate for urban areas in Nigeria. It has a city area of 44 sq mi (113 km2) and the metropolitan area of 80 sq mi (200 km2).

In terms of geology, the town lies in the eastern Nigeria sedimentary basin, underlain by Enugu shales, lower coal measure (Mamu formation) and false bedded sandstone (Ajalli formation). Its topographical features are classified into two; the escarpment zone, the plains and lowlands of Cross River Basin. Average maximum temperature is usually a little above 27˚C all over the year although it sometimes exhibits peak of up to 36˚C in March, which is usually the hottest month of any year. Average annual rainfall is about 1800 mm but over 70% of the amounts fall in four months, between June and September. According to (Nwoke et al., 2020), empirically the urban area is zoned into six for managing the solid waste. The zones are: Agbani boulevard, Emene, Abakpa Nike, Coal camp, Ogui and New Heaven zone (Figure 1). The onus is on each zone to collect and transport the waste to Ugwuaji landfill. Great quantity of the generated waste in Enugu urban municipality is dumped of at Ugwuaji open dumpsite, in Enugu. This method of waste management has some disadvantages which among others are methane emission and production of leachate (Nwoke et al., 2020). For that reason, this study is done to present some approaches for recovery of energy by the treatment of waste towards lessening the environmental burden.

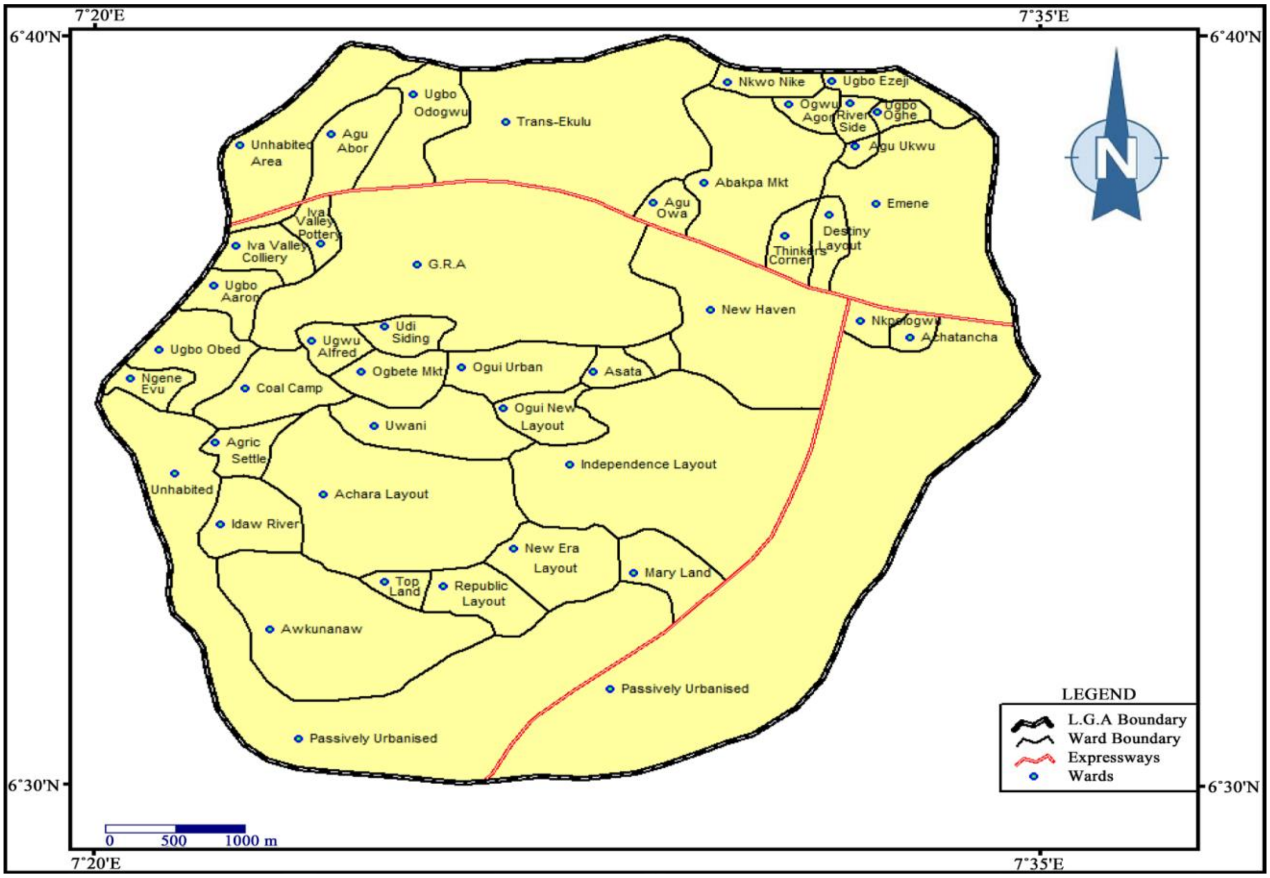

Figure 1. Map of Enugu Urban Area (Ezenwaji et al, 2016)

METHODS OF DATA COLLECTION

This study makes use mostly of literature survey and secondary data, which came from Books, Records, Published censuses (National population reports) or other statistical data (National Bureau of Statistics), Data archives (Enugu Electricity Distribution Authority), Internet articles, Research articles by other researchers (journals), Databases, etc., for discussion and analysis.

DATA ANALYSIS AND PRESENTATION

The data for this study was analyzed using statistical method of data analysis. The presentation makes use of tabular and diagrammatic presentation types. It actually employs geometric diagram (bar charts, pie charts and frequency diagrams) to present the data.

RESULTS AND DISCUSSIONS

At the landfill at Ugwuaji based on the generation zone as shown in figure 2, according to (Nwoke et al., 2020), the municipal solid waste (MSW) composed physically on average 39% organic matter, which has high fraction vegetables and food waste. Others are as shown in the Table 2.

Table 2 Average composition of Enugu urban solid waste

Waste constituents	% Composition
Organic matter	39.0
Plastics	21.0
Paper	16.0
Textile	5.0
Metal	2.0
Glass	3.0
others	19.0

Source: Nwoke et al., 2020

The result showed that organic matter is the major constituent of MSW in municipality followed by plastics. The plastic constituent is majorly the lower dense polyethylene such as packs sachet water, biscuits, bread and other packaging materials. Others such as soil, ceramics, bones, are the third prominent constitute of MSW with 19%. These materials occupy small volume but have high weight content. Paper is the fourth with 11% followed by textile (5%), glass (3%) and lastly metal with 2%. Scavengers pick metal products from their primary disposal point before they get to the land fill site and this is makes it to have low percentage.

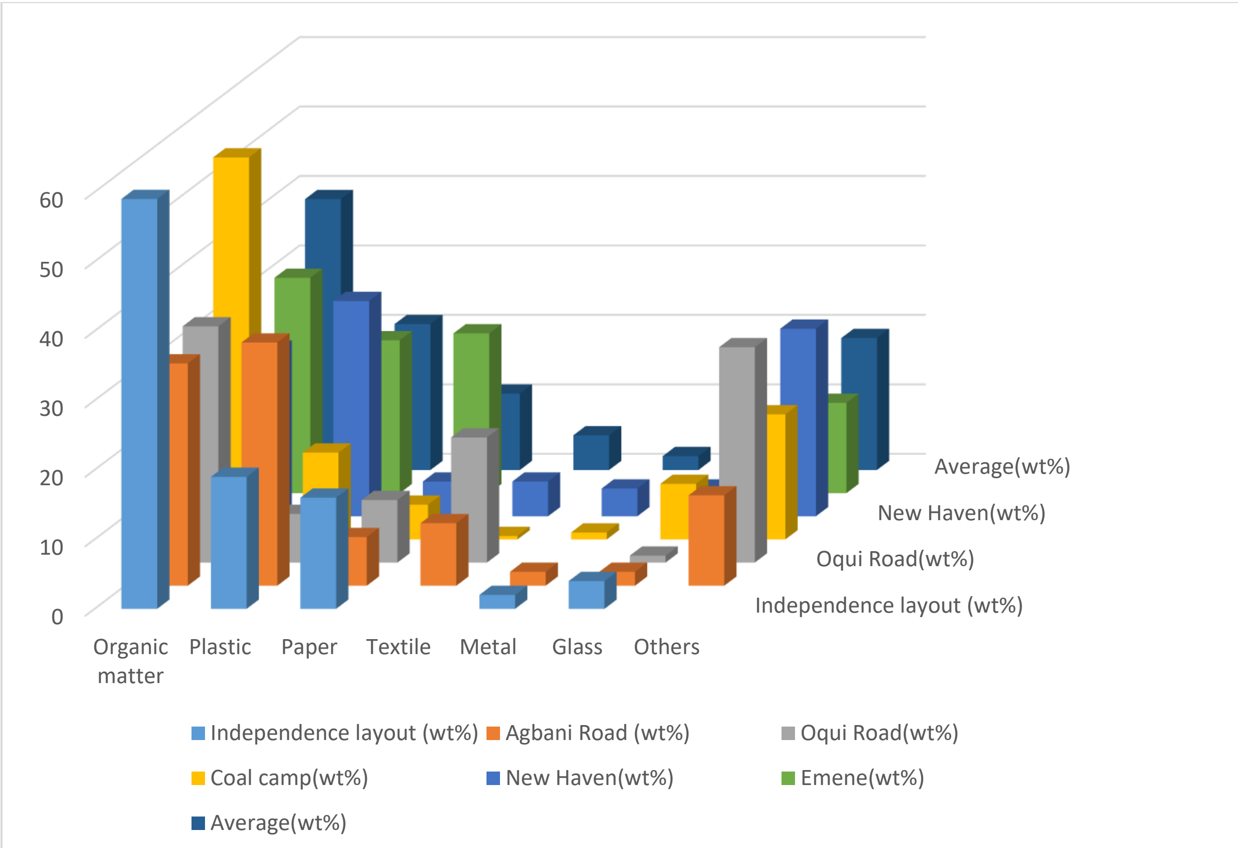

Figure 2. Physical composition of urban solid waste from various sectors
Data Source: (Nwoke *et al.*, 2020)

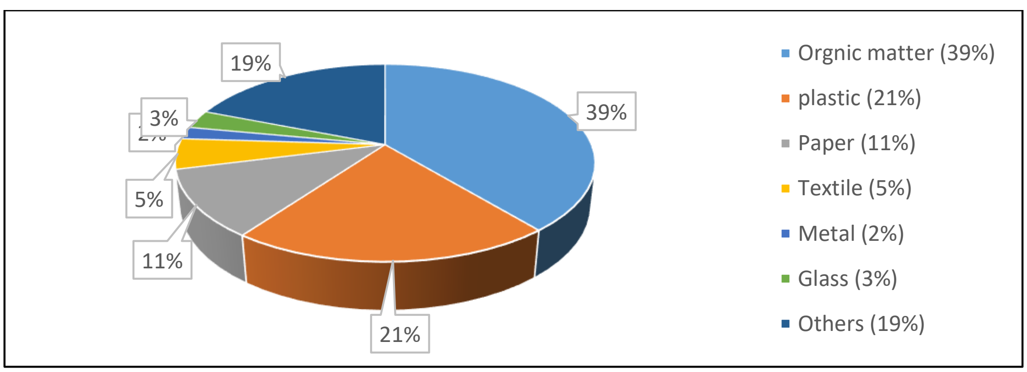

Figure 3: Enugu urban solid waste composition
Source : (Nwoke *et al.*, 2020)

The comparison of the result of physical composition of Enugu municipality waste stream between the previously done research by other researchers with the current study for other major cities in Nigeria as presented by (Ogwueleka, 2009 ; Nwoke et al., 2020) shown in table 3 and figure 4.

Table 3 Characteristics of waste stream compositions in Nigeria

	Organic matter	Plastics	Paper	Textile	Metal	Glass	Others
Onitsha	30.7	9.2	23.1	6.2	6.2	9.2	15.4
Nsukka	56	8.4	13.8	3.1	6.8	2.5	9.4
Lagos	59	4	14.0	-	4.0	3.0	19.0
Kano	43.0	4.0	17.0	7.0	5.0	2.0	22.0
Ibadan	76	4.0	6.6	1.4	2.5	0.6	8.9
Maidugri	25.8	18.1	7.5	3.9	9.1	4.3	31.3
Markurdi	52.2	8.2	12.3	2.5	7.1	3.6	14.0
Enugu CR	39.0	21.0	11.0	5.0	2.0	3.0	19.0

Note: Others = ash, rubber, soil, bones, dust
CR= current Research
Source : (Nwoke et al., 2020)

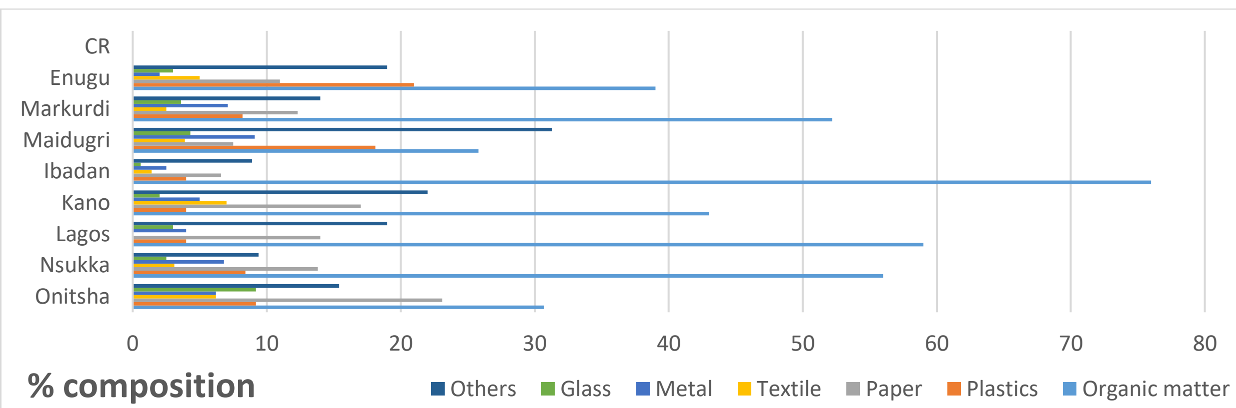

Figure 4 Characteristics of waste stream compositions in Nigeria

It can be seen from Figure 4 and Table 3 that the physical composition of the current work trails the same inclination with the research done previously other researchers in Nigeria. (Diaz and Golueke, 1985; Ogwueleka, 2003; Ogwueleka, 2009; Agunwamba, 1998; Cointreau, 1982; Dauda; Osita, 2003 and Nwoke et al., 2020).

Opportunities in Enugu urban solid waste

Recollecting the influence of population expansion and increase in economic activities in Enugu urban, it is essential to look out for a possible means of addressing the situation. Managing waste and efficient supply of energy are obviously challenging issues in Enugu urban. Although, hydropower in Nigeria has enormous potential to generate electricity, however, it does not solve satisfactorily the problem. WTE concept, no matter the generated amount, can enhance energy supply Enugu urban dwellers. Presented in this section is the urban solid waste to energy conversions.

The Energy Content of Solid Waste in Enugu urban area

As solid waste contains different components so also there are differences in the calorific values of the individual components. In order to determine the heat content of solid waste, it is vital to not only know its composition but also its moisture content. Various sectors composition of solid waste in Enugu urban area are shown in figure 2 likewise collective Enugu urban solid waste composition figure 3. To determine the heat content of solid waste, the heat values of individual solid waste component is used. Table 4 shows the heat values of on dry basis, of various materials. The below formula is used to calculate the heat content of solid waste.

Heat content (HC) = Xi * HVi

where Xi = the fraction of component *i*

HVi = Heat Value of component *i*

Thus, the heat content of Enugu urban area solid waste is simply calculated as:

HC = 0.39 * 7.6 + 0.21 * 22.6 +0.11 * 6.7 + 0.05 * 13.8 + 0.02 * 0.7 + 0.03 * 0.1 + 0.19 * 41.3
= 17.001 million Btu

From the analysis it is obvious that each ton of Enugu urban solid waste has the potential to generate 17.001 million Btu.

It means that every day, a total of 5.0 MW energy theoretically can be generated from solid waste in Enugu urban area. If organic waste is the only one incinerated (as other components can be recycled or reused), it will generate about 2.96 million Btu (1.1MW), which is adequate to light just about 900 households. The amount produced is not that much, however, it is not that small to be ignored.

Table 4. Average heat value of possible components in Solid waste

Waste Component	Heat Value (Btu/ton x 10^6)
Plastic	22.6
Rubber	26.9
Leather	14.4
Textiles	13.8
Glass	0.1
Organic waste	7.6
Paper	6.7
Metal	0.7

(Source: Shrestha *et al.*, 2014**)**

Government Plan and Support

The execution of waste to energy concept involves reasonably great start -up investment. Full government support is needed. With the emergence of solid waste management innovative technologies, Enugu State Government, in order, to assist the Enugu State Waste Management Authority (ESWAMA) get rid of waste that is beginning to grow on dump locations in the city has constituted a 12-man committee charged with the responsibility of providing unprecedented efficient waste management services to all its domestic, industrial and commercial clients, government inclusive. The committee has already brought relief to the residents, with its partnership with private refuse collectors, who are assigned each of the 29 zones created to ensure better management of the wastes. The state government has also kick-off its programme on waste to wealth aiming at harnessing a novel line of economic activities and engaging interested investors through providing enabling environment for resources management, environmental protection by means of re-using and re-distribution of unwanted materials.
The Enugu state government is considering a partnership with Serene Green Field and Portland Waste to Energy in the waste management and disposal and to eventually grow the waste to an extent of generating energy and fertilizer (https://guardian.ng/property/enugu-begins-solid-waste-reform-partners-private-sector/) . Besides, transforming waste into energy will mitigate the level of air and water pollution, thus offering improved environment and significant energy production for the people. These impalpable benefits are frequently overlooked.

SUMMARY, RECOMMENDATION AND CONCLUSION

The management of solid waste is a multi-variable problem. Basically in Enugu municipality, the problem is still at the rudimentary level. Numerous challenges are bound to be faced by the government, populace, private sectors and any other stakeholders. The technology, technique, public awareness, financial and management problems are some of the issues to be faced. Conversely, there are various substantial opportunities to be noted. The potential of solid waste to energy, the sponsorship from government and private sector participation would be the premeditation for progress.

RECOMMENDATION

- Government should set up strong policy on solid waste management and also offer with clear standard on the waste collection and transportation technique.
- It can make the landfill site so hygienic.
- Replacement of open dump with sanitary landfill.
- Anaerobic digestion is thought of to be the most economical solid waste to energy conversion technology. Ultimately, private sectors support will be needed by the government in procuring technology to convert solid waste into gas or electricity to have energy demand fulfilled.

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