

Full length Research paper

Assessment of bioenergy potential from MSW in Urban Municipalities of Nigeria

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In Nigeria the disposal of waste in dumpsites whether approved or not certainly is an inefficient material management as it does not bring financial returns at the end point of the waste management system and it is also unsustainable. However, this is the case of Nigeria's waste management system. This has led to environmental, health, and aesthetic damage as well as depletion of natural and economic resources. This study was conducted in University of Benin, Ugbowo campus, Benin City, Edo State with the aim of investigating the bioenergy potential from solid waste by quantifying, characterizing and determining the bioenergy obtainable from waste generated within the University community. Stratified systematic sampling method was adopted and seventy nine (79) sample sites were chosen. The wastes generated are majorly household wastes which are food, plastic, paper, metal, glass, combustibles and lignin materials. The result revealed that fruit and food waste generated a mass of 916.60kg and 2792.63kg respectively. Based on this, about 37% of the waste generated had the potential for bioenergy production. This will result in an expected 968.30m³ of biogas to be generated in total per day. The bioenergy technology like the bioethanol plant with fractional distillation unit and bio digesters should be considered as the best treatment method as it is clean, sustainable, efficient and creates wealth.

Keywords: *Municipal Solid Waste, Dumpsite, Environment, Waste Management, Bioenergy*

INTRODUCTION

Municipal solid waste is defined to include refuse from households, solid waste from industrial, commercial, and institutional establishments (including hospitals), market waste, yard waste, and street sweepings (Ogweleka, 2009). In urban areas, especially in the rapid urbanising cities of the developing nations like Nigeria, problems and issues of solid waste management (SWM) are of immediate importance. The first step in waste management is to gain an understanding of the waste types being generated to design appropriate collection and disposal strategies and this can be achieved through characterization of waste (Biose, *et al.*, 2021). In developing countries, local authorities spend 77-95%

of their revenue on collection and balance on disposal (Ogwueleke, 2003), but can only collect almost 50-70% of MSW. In Edo State, the ministry of Environment and public utility (MEPU) is the regulatory body with the responsibility of managing the environment on behalf of the state government; which in turn set up the Edo state waste management board (ESWMB), to oversee the collection, transportation, processing, recycling or disposal of all type of waste generated within the state. In managing the environment, the ministry tackles all environmental problems ranging from waste management, flood and Erosion control, forest depletion and general environmental and atmospheric pollution. Suffice to say, the current waste situation in the state highlights the inefficiency of the Ministry and Board to sustainably tackle waste management in the state (Igbinomwanhia, 2011). Consequently, increasing populations, economic growth

and affluence have majorly contributed to increasing generation rate of Municipal Solid Waste (MSW) causing a major challenge to its management (Aguilar-Virgen, *et al.*, 2010; Al-khatib *et al.*, 2010; Fakare *et al.*, 2012; Nabegu, 2010). Cities in Nigeria, being among the fast growing cities in the world (Onibokun and Kumuyi, 1996) are faced with the problem of solid waste generation. By 2025 with a projected population of 233.5 million, Nigeria will be generating an estimated 72.46 million tonnes of waste annually at a projected rate of 0.85 kg of waste/capita/day (Suhaib, 2021).

The lack of proper municipal solid waste management in developing countries, especially Sub-Saharan Africa has a significant impact on the environment and human health. Moodley and Trois 2022; Ahmed, *et al.*, 2023; Peng, *et al.*, 2023 notes that improper management of MSW contributes to greenhouse gas emissions including methane from organic waste.

The lack of adequate waste management practices in developing nations of the world is a significant health concern and poses a serious risk for pathogen spread. The indiscriminate disposal of municipal solid waste in developing nations is often linked to poverty, bad governance, urbanization, population increase, low living standards, lack of environmental consciousness, and insufficient environmental knowledge management (Fattah, *et al.*, 2022; Roy, *et al.*, 2022; Ajinawo and Aribasoye, 2023). This menace has led to diseases such as cholera, malaria, and hepatitis B virus (HBV), as well as significant health risks, such as gastrointestinal issues, eczema, asthma, cancer, and bronchitis.

In addition, the growing interconnectedness between urban lifestyles, recycling, and goods, efficient municipal waste collection, transportation, and disposal remain a

complex environmental service. The implementation of effective municipal solid waste management practices can reduce the negative impact of waste on the environment, human health, and the economy, while promoting sustainable development.

People should be orientated knowledgably to perceive waste as being a valuable resource for material and energy recovery. The potential of using municipal solid waste (MSW) as feedstock for bioenergy production is not in doubt (Biose, *et al.*, 2021), since about 60% of MSW is carbonaceous, consisting of materials which can either be biodegraded into fuels like biogas and bioethanol thereby generating utilizable energy (Bolam, *et al.*, 2013; Beyene, *et al.*, 2018; Chai, *et al.*, 2016; Dhar, *et al.*, 2017; Johari, *et al.*, 2012). The two major technologies for bioenergy production from municipal solid waste are anaerobic digestion for biogas and fermentation to fractional distillation for bioethanol.

A previous study investigating the potential of commercializing biogas and bioethanol from municipal solid waste in Benin City (Kubeyinje, *et al.*, 2021; Biose, *et al.*, 2021) revealed that bioenergy technology could be a preferred method for sustainably managing municipal solid waste. Therefore this paper focuses on the assessment of bioenergy potential from MSW in urban municipality of Nigeria taking Edo State as a case study.

STUDY AREA

The University is located in Egor Local Government area of Edo state with major activities focusing on teaching, research and community services. In carrying out these functions, academic, administrative, residential and commercial spaces are provided.



Figure 1.0: Map of Egor Local Government Area, Edo State (Google Map, 2020)

MATERIALS

Printing of questionnaires, sample notes, pamphlets and the procurement of baskets, wheelie bins and bin bags were deployed to the field for training and behaviour

towards waste by respondents and waste characterisation purpose. The questionnaires were used to obtain information on the status, life style, class, level of awareness on waste management etc. Sample notes were designed to obtain information on the various

streams of waste generated while the pamphlets were designed to help sensitize respondents and sanitation officers on waste sorting. The bin bags were coded in colours for different various waste streams. Other materials were weighing balance, stationeries, coverall, buckets and personal protective materials like boots, nose masks, gloves and hand sanitizers.

METHOD

A preliminary survey was conducted on the University of Benin community (Ugbowo campus) in order to obtain reconnaissance information on the layout of the University community. Every building in the University was documented during this survey and it was on this basis that the stratified sampling systemic method was adopted to get a homogenous sample size and diversity of the study area. Following the preliminary survey, visitations were made to respondents to sensitize them on the aim and objectives of the study and also seeking for their cooperation with the research team.

Data was collected through primary and secondary sources. Primary data were collected through preliminary survey, face-to-face interviews and questionnaires to get information on the current waste practices in Benin metropolis (University of Benin Community as case study). Secondary data were gotten from published and unpublished reports.

The University community was divided into 3 strata's based on the activities and type of waste generated. The

strata's were residential, commercial and academic/administrative.

A combined sample size of 1164 samples was achieved for the duration at three (3) days interval. Ninety seven (97) sample sites were visited which was above the minimum number of households of 50 per 500 households suggested by EPA (1996).

Research assistants were trained on the mode of waste sorting and proper disposal of waste generated. The waste was sorted into three colour codes of bin bags differentiating fruits and food waste for bioethanol and biogas production respectively and another colour coded bin bag for other waste stream. The bag for other waste stream was further sorted insitu into paper, plastic, metal, ceramics, leaves and combustibles. Data on the weight of each of these streams of waste was recorded. Observations on the conditions of the waste were also taken into record.

In a second phase of the study, the per capita generation was determined using the formula:

$$\text{Per capital waste generation} = \frac{\text{weight of MSW generated}}{\text{Total Number of persons} \times \text{Total generation days}}$$

The total Generation rate was obtained by multiplying the per capita generation by the total population.

Obtainable biogas was determined from organic fraction of the waste following the same equation adopted by Akhator, *et al.*, (2016).

Total biogas obtainable = Amount of food waste (t) × VS (%) × Biogas yield (m³/t VS)



Image 1.0: Resource materials (wheelie bins, waste baskets and bin bags)



Image 2.0: Sorted Waste and Characterization of MSW by the research team



RESULT

The data obtained through the administration of site

specific sampling and interviews were analyzed using tables, pie-charts and percentages below;

Table 1.0: Municipal Solid Waste Generated in the study area

Residential Area								
Fruit (kg)	Food (kg)	Plastic (kg)	Paper (kg)	Glass (kg)	Metal (kg)	Combustible (kg)	Leaves (kg)	Ceramic (kg)
724.40	1806.5	1050.40	662.80	130.3	70.24	1002.40	0	47.50
Commercial Area								
Fruit (kg)	Food (kg)	Plastic (kg)	Paper (kg)	Glass (kg)	Metal (kg)	Combustible (kg)	Leaves (kg)	Ceramic (kg)
166.55	816.17	765.49	364.66	24.49	34.71	8.11	208.16	0
Administrative/Academic Area								
Fruit (kg)	Food (kg)	Plastic (kg)	Paper (kg)	Glass (kg)	Metal (kg)	Combustible (kg)	Leaves (kg)	Ceramic (kg)
29.56	169.96	1175.34	595.24	50.65	66.44	30.11	71.77	0

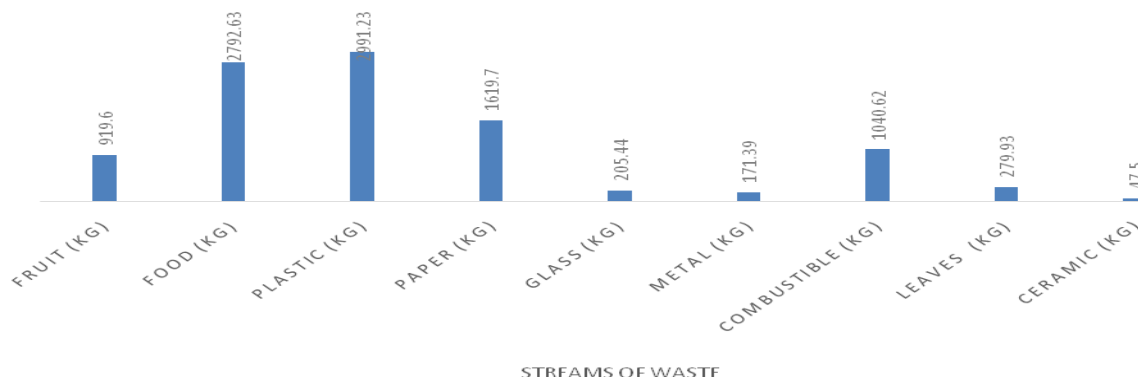


Figure 2.0: Total volume of waste streams generated in Study Area

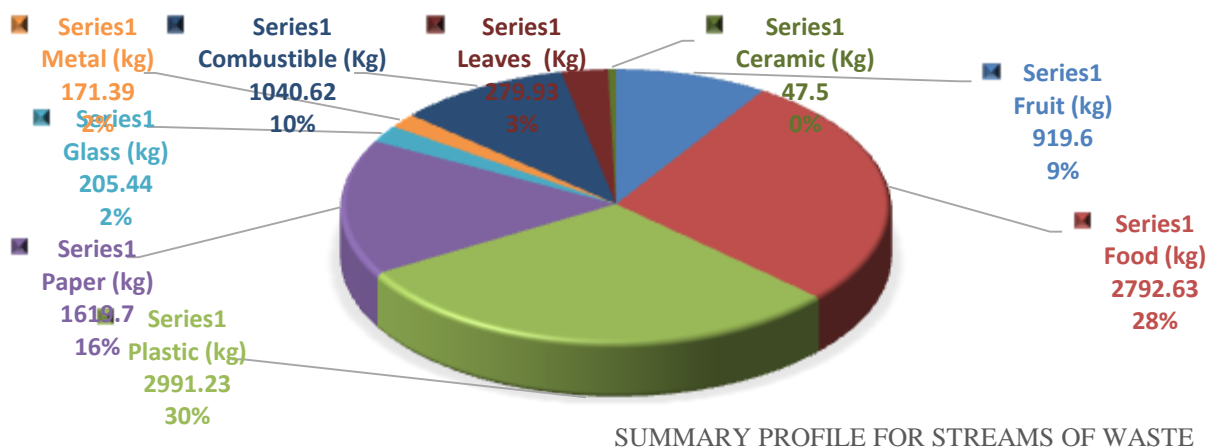


Figure 3.0: Profile of Waste Streams generated in the Study Area

DISCUSSION

The charts and graphical representation as displayed above shows the total volume of waste streams generated in the study area. For the purpose of this research, organic waste was sorted into food and fruit waste to achieve the aim of the study in determining the bioenergy potential from municipal solid waste. The total waste generated in the study area from figure 3

shows that high volume of plastic and organic waste was generated by respondents in the residential and commercial areas. Figures 2 and 3 shows that plastic and food waste generated 30% and 28% (2991.23kg and 2792.63kg) respectively this is obviously due to the fact that respondents engaged in domestic activities such as cooking and eating especially in the residential area. However, the food court which falls within the commercial strata generated high volume of organic and plastic

waste because they perform the above domestic activities on a large scale. This finding, establishes that food waste is the second most generated waste in the study area hence making it one of the most readily available for bioenergy production in the form of biogas for heating, cooking and even power generation. Paper waste was 16% (1619.70kg), combustible and fruit waste had 10% and 9% (1040.62kg and 916.60kg) respectively. The fruit waste comprises of watermelon, oranges and pineapple which can be harnessed for bioethanol production.

The commercial and administrative/academic areas respectively generated more volume of plastic and paper waste as compared to the residential area and less biodegradables. This result was in line with previous studies by Igbinomwanhia (2011) revealing biodegradable waste 14.56% in administrative block of the University of Benin. However, the student hall of residents which falls under the residential area generated a high volume of combustibles than any other residential respondents; this was due to the population of respondents (students) but also consumption patterns of students as against family, as most students consume more of fast food packaged in plastic and paper. The combustible materials in this project comprise of Styrofoam materials, wood chip and textile.

CONCLUSION AND RECOMMENDATION

This project was carried out within the University of Benin community. The study area was divided into three (3) strata's namely residential, commercial and administrative/academic areas. The waste generated from this areas are majorly household waste which are food, fruit, plastic, paper, metal, glass, combustibles and lignin materials. This work made use of primary and secondary data.

A recognisance survey and preliminary study was conducted which assisted in the adoption of using the stratified systematic sampling method.

Characterization and quantification of solid wastes play a significant role in estimating material and energy recovery potential and determining sources of generation, treatment methods, and final disposal. This study illustrates that of the total waste generated, 40% is easily compostable and or biodegraded under controlled conditions to produce biogas. On the other hand the fruit portion of the organic waste can be easily subjected to fermentation and bioethanol can be distilled. Research is on-going in investigating the potential for bioethanol production from paper waste and this study reveals a substantial amount (16%) of paper waste. Along with the recovery of substantial energy; bioenergy technologies will also lead to a substantial reduction in the overall waste generated in Nigeria if adopted and bring about a sustainable waste management system.

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