CHARACTERIZATION OF MUNICIPAL SOLID WASTE IN ENUGU METROPOLIS FOR OPTIMAL MANAGEMENT STRATEGIES

ABSTRACT

This study characterizes solid waste in Enugu Metropolis, Nigeria, to inform sustainable waste management strategies in the region. Traditional and simpler material-based classification approach was employed in this investigation. Individual household samples were collected in black rubbish bags labeled with a unique identifier. Air oven method was used for waste moisture content determination. A total of 300 waste samples were collected using identified waste collection bags from middle-income, high-income and low-income households and analyzed for physical and chemical composition. According to the study, biodegradable matter accounted for 40.16% of the total solid waste generated in the study area, while non-biodegradable matter accounted for the remainder which is 59.93%. The study area's per capita trash generation ranged between 0.36 and 0.67 kg/capita/day. Using the results of this characterization study as a guide, the results clearly indicate the necessity to create formal composting (for 40.2% of the waste) and recycling (for 59.93% of the waste) facilities within the Enugu Urban region. However, the current waste management practices are inadequate, due to several factors ranging from poor funding, unskilled personnel, inadequate collection vehicles, poor collection routes and so on which leads to environmental and health hazards. The study recommends implementing a decentralized waste management system, promoting recycling and composting, and developing a waste-to-energy strategy to address the waste management challenges in Enugu Metropolis.

Keywords: *waste recycling, waste recovery, biodegradable, waste generation; waste characterization; ESWAMA*

1. INTRODUCTION

The quest for urbanization in Nigeria has exacted massive pressure on cities, towns and surrounding areas thereby leading to increased urban waste generation with resulted effect in health hazards, underground water pollution and poor aesthetic qualities.

The composition and quantity of waste generated and disposed vary both in pace and time in relation to human activity, socioeconomic status, presence and size of industry, and the quantity and type of products that communities consume (Hudson 2007). Characterizing municipal solid waste involves

analyzing its components in terms of quantity and quality, considering factors like location, seasonality, and waste management infrastructure. This process helps identify the categories and quantities of wastes like food-waste, paper, and glass in the waste stream. By characterizing municipal solid waste, we can determine the volume of generated waste in a specific area at a given time, which will enable effective waste management approaches that protect community health and environment.

In Nigeria, obtaining accurate data on waste composition is a significant challenge, hindering the growth and progress of waste management, unlike in industrialized countries.

This research study is based on the environmental health difficulties linked with waste pollution, and because it is a major worry for the developing world's rising population, it is critical to identify and understand the impacts and causes of these problems. It has been noted that bad route design, incorrect collection systems, poor road network, poor collection schedules and insufficient organization all have an impact on waste collection and transfer (Hina *et al*., 2020). Because of insufficient labour, equipment, and government budget for disposal system and procedure, solid trash cannot be packed and hoisted on a consistent basis, increasing operational costs. Moreover, garbage collection and transportation take place during the day, when individuals are more vulnerable to hazardous waste and dangerous compounds from industry and hospitals. To address this, municipal waste can be characterized through chemical/laboratory or physical/manual methods of determining its composition. It is critical to understand the composition and characteristics of municipal solid waste (MSW) in order to design successful waste management methods. It aids in the development of effective collection, sorting, treatment, and disposal systems. Understanding the composition of MSW also aids in identifying valuable materials that can be recovered and sold as commodities, contributing to the local economy. It also helps in evaluating the costs associated with waste management and identifying opportunities for cost savings. MSW characterization will also provide insights into potential health hazards associated with certain types of waste. It helps in identifying hazardous materials that require special handling to protect the health and safety of waste workers and the general public.

This study is aimed at characterizing and Analyzing the Municipal Solid Waste Stream in some selected households within Enugu metropolis. Therefore, the specific objective is to carry out physical analysis of

waste composition and assess current management practices and resource recovery potential for sustainable waste management practices in Enugu State.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study area is Enugu metropolis, the capital of Enugu state Nigeria. It is located between latitudes 6020` N and 6032`N of the equator and longitudes 7028`E and 7036`E of the Greenwich meridian. It extends over an area of about 145.8 square kilometres (Enugu State Ministry of Lands and Survey, 2022). The area is administered by three Local Government Authorities namely: Enugu North, Enugu South and Enugu East Local Government Areas (LGAs). Enugu metropolis is bounded in the north by Isi-Uzo and Igbo Etiti LGAs, in the west by Udi LGA and in the South and East by Nkanu West and Nkanu East LGAs respectively (Fig. 1). Enugu metropolis as a geographical entity has many administrative divisions basically into: LGAs, zones, wards, layouts among others. Available records in the ESWAMA main office indicates that Enugu metropolis was divided into ten (10) zones based on their SWM coverage schedule. The ten ESWAMA zones of Enugu metropolis includes: Abakpa, Trans-Ekulu, Emene, Idaw River, GRA, Ogui, Independence Layout, Agbani Road, Uwani and New Haven (Fig. 2). Table 1 shows that the ESWAMA zones cover the three Local Government Areas (L.G.As) that make up Enugu Metropolis.

Table 1: The ESWAMA zones of Enugu metropolis and some of the wards/layouts in each zone

S/No	Zones	Wards / Layouts
1	Abakpa	Abakpa 1&2 and Nike
8	Agbani Road	Awkunanaw and Gariki
3	Emene	Emene and Thinkers corner

5	GRA	GRA and Ogbete/Coal camp
4	Idaw River	Idaw River and Ngene Evu
7	Independence Layout	Independence Layout and Maryland
10	New Haven	New Haven and Asata
6	Ogui	Ogui and Ogui New layout
2	Trans-Ekulu	Trans-Ekulu and Ugbo Odogwu
9	Uwani	Uwani and Achara Layout

Source: Author's field survey, 2024.

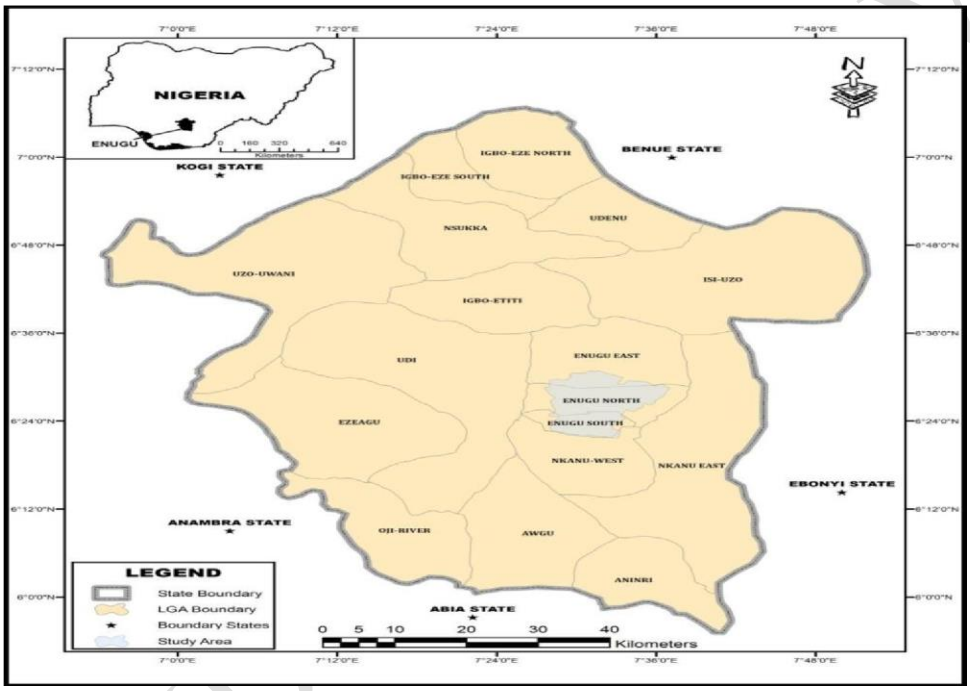

Fig. 1. Enugu state showing the study area

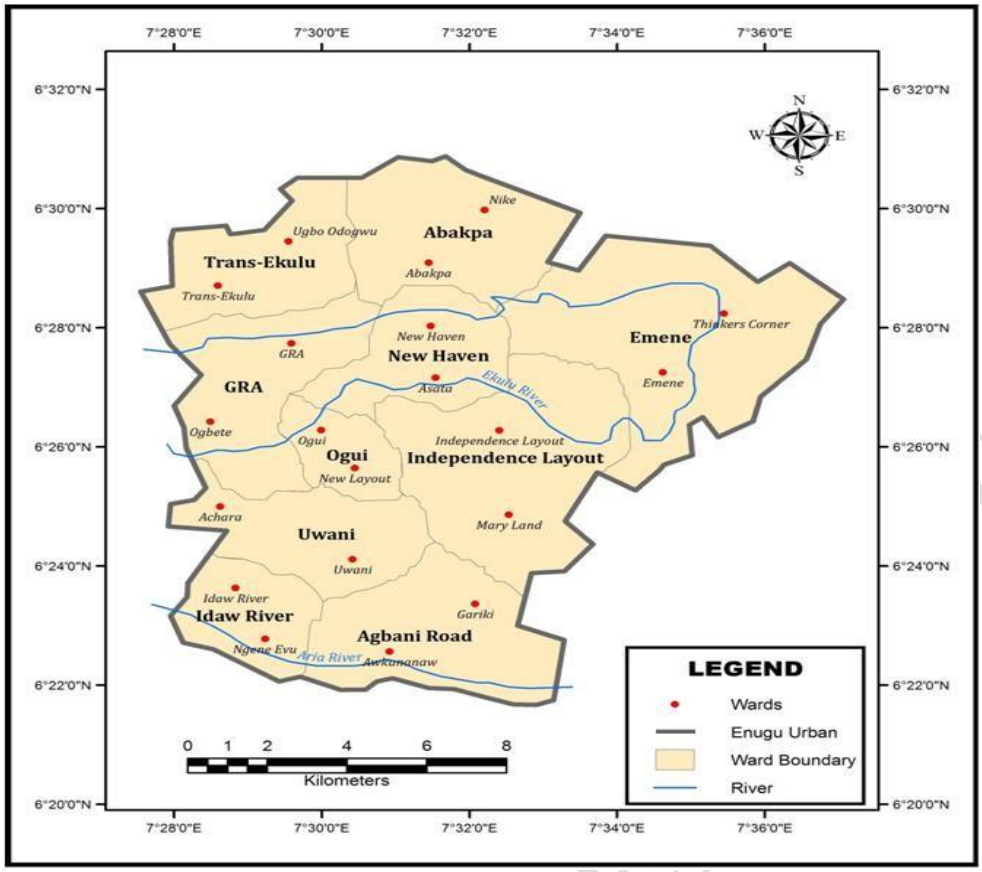

Fig. 2. Enugu metropolis showing the ESWAMA zones

2.2 Method of Data Collection and Analysis

Both primary along with secondary sources were the two main data sources used in the study. Personal observations, formal questionnaire administration and surveys are examples of primary sources. Journals, past literatures, periodicals, textbooks, the Internet, and magazines were the sources from which secondary sources were taken. Research assistants were engaged in the questionnaire administrations to the respondents. The assistants were dispersed to different areas within the metropolis. Explicit instructions were provided to help fill the instrument. The structured questions comprised the questionnaire instruments. 399 copies (based on sample size calculation) of questionnaires were administered and followed up to ensure that all copies were retrieved.

2.2.1 Waste Compositional Study

Traditional and simpler material-based classification approach developed by Burnley (2007) and Oyelade (2019) was employed in this investigation. Individual household samples were collected in black rubbish

bags labeled with a unique identifier. Collected samples were transported to a sorting facility, where they were weighed to determine the overall weight of the sample, then segregated into paper, cardboard, plastic film, dense plastic, glass, metals, non-ferrous metals, Putrescibles, textiles, miscellaneous combustibles, miscellaneous non-combustibles, Waste from Electrical and Electronic Equipment (WEEE), Hazardous Household Waste (HHW), and fine components. The weights of the separated components were determined as a percentage of the sample's total weight. Approximately 1kg of each sample material were collected in polyethylene bags and delivered to the materials laboratory for moisture content analysis. Each sample's analysis is required to be completed within a day to reduce errors caused by field conditions. Data collected will be statistically analyzed using data visualization such as scatter plots, bar charts, line graphs and tables, to identify significant similarities and differences for better understanding.

2.3 Moisture content determination

Air oven method was used for waste moisture content determination. This method is based on moisture loss on drying at oven temperature of 105^{o}C. Besides water, the loss will include other matters volatile at 105^{o}C**.** Materials used in the waste moisture content determination include:

i. Flat bottom silica dish
ii. Thermostatically Controlled Hot Air Oven with Fan
iii. Analytical Weighing Balance
iv. Desiccator

Three samples were collected at random from the three categories used from the study area. All the samples were analyzed in duplicates and the results obtained using equation 3.1.

$$Moisture\ Content\ \% = \frac{Wet\ Sample - Dry\ Sample}{Wet\ Sample}\ x\ 100 \qquad 3.1$$

2.4 Design of survey questionnaires

The study included distinct questionnaire surveys that include homes, businesses, and waste policymakers, as well as a government body tasked with waste management in Enugu (ESWAMA). The formats of the questionnaires are similar and responses reflect the intended group. The rationales for selecting questions were: (1) the necessity to collect data which, when analyzed, may help accomplish the research's immediate objectives; and (2) to collect data in critical areas of MSW management in the

City where none now exist. Kineber *et al*. (2020) has recognized the core components of an effective survey and pushed for best practices in questionnaire design and administration. Following their advice, the questionnaires were developed for self- or guided completion and intended to be quick, easy to read, and understand; absolutely free of bias or ambiguity.

Ten days of sampling was carried out for each location and questionnaires were administered. The questions were structured to extract the households' economic-demographic variables. Labeled garbage bags (Day 1 to 10) were delivered prior to the collection period on a daily basis, that is, on the eve of the first day, a garbage bag labeled Day 1 was delivered and collected the following day, and another garbage bag labeled Day 2 was delivered for collection the next day until the 10 days period was over. The generated household garbage and questionnaires collected were transported to the study center on a daily basis for the 10 days period. First, the mass and loose volume of collected household garbage was measured. The garbage was then sorted and the components weighed. The waste components were re-mixed, and compacted, and the compact volume measured. The method was repeated until a sample of 10-day data was obtained. This was replicated for the other 2 locations and the data from 30 households was used in the analysis. In the sampled data, the contributions of the economic strata were under the following factors: percentage of low-income earners, the percentage of middle-income earners, and the percentage of high-income earners.

According to Yamane (1964), the sample size of the respondents for the questionnaires administration was based on the following equation by Yamane (1964);

$$n = \frac{N}{1+N(e)^2}$$

Where;

n = Sample size

N = Population Size = 284,200

e = Significance Level (0.05)

2.5 Data Analysis Method

The questionnaires were administered to three categories of respondents: households, businesses, and policymakers in government agencies in Enugu Metropolis responsible for waste management. In all cases, it was ensured that respondents are those residing or have businesses within the study area. Two sets of data were obtained from the waste compositional analysis and the questionnaire survey. Analysis of data from the waste composition study was carried out using Microsoft Excel for Windows.

2.5.1 Descriptive Statistical Analysis

Descriptive statistical analysis therefore involved the use of frequencies, percentages, means, and standard deviation to describe various variables encountered during the study. These techniques were employed for analyzing data relating to the characteristics of the respondents or organizations they represent. Graphical representation will also be utilized to present the results from these analyses and this will include pie charts, bar charts, and tables.

3. RESULTS AND DISCUSSION

3.1 Socio Demographic Data of Sampling Area

Enugu Municipal Area was selected as the sampling area with particular reference to towns and areas that broadly captures the range of socio-demographic characteristics that exist in most parts of the City which are relevant to this study (Table 2). These results were as a result of questionnaire administered in the study area. The district was sub-divided into three sampling zone according to the methods developed by Parizeau *et al*. (2006), which are; Obiagu/New Layout, New Haven, and Independence Layout. Table 2 shows an overview of socio demographic characteristics of sampling area.

Table 2: Overview of socio demographic characteristics of sampling area

Sample Area	No of household sampled	Geographical Description	Demographical Classification	Average Household Size	Income Classification
1	10	Obiagu/New Layout	High-Density	9-10	Low-Income
2	10	New Haven	Middle-Density	7– 8	Middle-Income
3	10	Independence Layout	Low-Density	5 – 6	High-Income

3.2 Overview of Data Collection

Municipal Solid Waste (MSW) was taken at ten different households in Independence Layout area of the metropolis. Samples collected from various households were taken to the Study center, the total weight of the waste composition was weighed, and the data reading was recorded. Sorting and weighing of seven different components were carried out as well. The various physical quantities of waste generated were measured in Kilograms and their weights recorded. This was repeated for 10 days and a total of 100 samples were obtained from this zone. In all, a total of 300 waste collection bags which represents an average of 30 bags daily from the 3 sample areas were obtained as shown in Figure 3.

Figure 3: Samples collected from sample areas taken to the facility for weighing

3.3 Analysis of Results

3.3.1 Moisture Content Analysis

Municipal Solid Waste samples were randomly selected from the households used in the study: 10 households in low-income area, another 10 households in middle-income areas and also 10 households in high-income areas. The approximate moisture content of waste samples from the study area was determined as detailed in the previous chapter. 15 grammes of wet samples (Ww) were weighed and

oven dried at 105°C for 24 hours. Final weights (W_f) of samples were noted at the end of drying. Dry weights (W_d) were obtained as the difference between final weight and weight of container (W_c). Moisture content was calculated as the difference between wet weight and dry weights (Hernández-Berriel et al., 2008).

$$Moisture\ Content\ \% = \frac{Wet\ Sample - Dry\ Sample}{Wet\ Sample}\ x\ 100$$

Table 3: Percentage (%) Moisture Content of Waste Samples

Sample	Method	Average Waste Moisture Content (%)
Sample A	Air Oven Method	29.58
Sample B	Air Oven Method	23.16
Sample C	Air Oven Method	35.48
Average		29.41

KEY:

Sample A: Solid waste from High-Income residential

Sample B: Solid waste from Medium-Income residential

Sample C: Solid waste from Low-Income residential area

3.3.2 Weight composition of waste samples from Low-Income household

Results of MSW Composition Analysis for Low-Income household Sample Area

Samples for this Low-Income household sampling area were collected mainly at Obiagu/New Layout of Enugu metropolis, a high-density neighborhood. The socio-economic classification of households in this sampling area is low to medium income, as described in Table 4.

Table 4: Percentage composition of Municipal Solid Waste in Study Area

S/No	MSW Category	Low-Income %	Middle-Income %	High-Income %
1	Food	18.967	22.045	41.735
2	Paper	10.892	13.478	13.366
3	Rubber	26.291	0.857	0
4	Plastic	31.643	50.143	34.752
5	Alum/Iron	5.164	5.14	3.601
6	Ceramics /Glass	7.042	8.338	6.547
		100	100	100

3.4 Discussion of Results

The analysis of questionnaire results of this study revealed that the rate of solid waste management in the study area does not promote urban development and therefore, not good for solid waste sustainable management. The study further revealed that solid waste management methods adopted is not effective and the alarming rate of deterioration of solid waste management in Enugu metropolis is caused by so many factors ranging from open dumping and littering, inadequate enforcement of waste management regulations, rapid urbanization and population growth, poor collection routes, inadequate vehicles, lack of skilled personnel and poor funding among others. However, the composition of waste samples from the three sampling areas is shown in Figure 4.

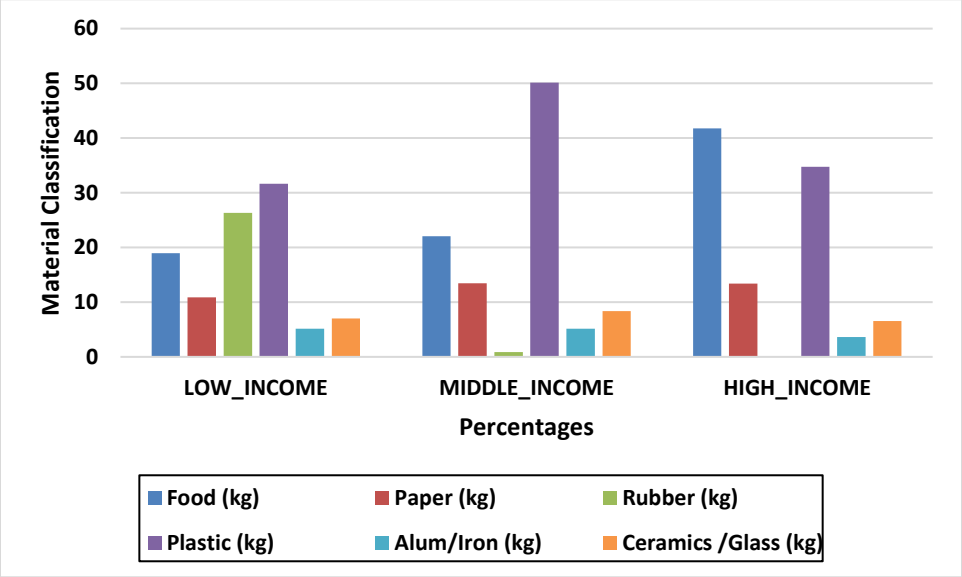

Figure 4: Composition of waste samples from the three sampling areas

The analysis of solid waste composition in this study as shown in Figure 4 for all the sampling areas indicates that 18.8%, 22.0% and 41.7% of the solid waste in low-income, middle-income and high-income households respectively are made up of food materials. The other composition are; plastics (31.6%, 50.1% and 34.8%; glass/ceramics (7%, 8.3% and 6.6%); metals (5.2%, 5.1% and 3.6%); Paper (10.9%, 13.5% and 13.4%) and rubber (26.3%, 0.9% and 0%). This indicates that composting/biodegradation can be used for the disposal of this 29.9%, 35.5% and 55.1% of biodegradable solid waste in the study areas

(and the fertilizer can be derived as the end-product of these wastes which is in line with Hoornweg *et al*. (1999).

High-income households have been observed to consume more organic matter (food) that give rise to a higher percentage of biodegradables (organic materials) like food remnants, peels and kitchen waste generally. This was found to be true as higher percentage of the organic materials (food) were influenced by the income rate. The research area's average per capita waste generation is predicted to be between 0.36kg/capita/days and 0.67 kg/capita/day, depending on the sampling area. Dauda and Osita (2003) found 0.25kg/capita/day in Maiduguri, Igbinomwanhia and Olanikpekun (2007) found 0.56kg/capita/day in Mushin, Lagos, and Solomon (2009) found 0.49kg/capita/day in average Nigeria villages with home and commercial centers. The range of 0.36kg/capita/day to 0.67kg/capital/day is determined by the people's socioeconomic position and consequently the location.

Presently in Enugu metropolis, there are no formal recycling and composting sites. Scavengers are so many, collecting useful objects for recycling in order to make a living out of the practice. These scavengers are usually young people who dropped out of school for one reason or another, with a few exceptions being individuals who made a living from it. Because they work without protective gear, the work is detrimental to their health (Ike et. al., 2018). Recycling is a more desired and environmentally sustainable solid waste management approach. Recycling and composting would reduce waste management costs (Ayilara *et al*., 2020).

Table 5: Percentage composition of Biodegradable, Nonbiodegradable and waste generated

Class of MSW generated.	Low-Income Household (%)	Middle-Income Household (%)	High-Income Household (%)	Average (%)
Biodegradable	29.86	35.52	55.09	40.16
Non-biodegradable	70.41	64.48	44.91	59.93
Waste generated per individual (/kg/capita/day)	0.36	0.67	0.55	0.53

The result of the analysis of MSW collection from low-income, middle-income and high-income households in Enugu metropolis was studied. The waste samples were collected from ten households in each category. Moisture content analysis was carried out on the waste collected and 29.41 % moisture

content was observed. Waste composition analysis was also carried out and it was observed that the wastes generated among the high-income household despite been low-density communities have highest biodegradable waste as against the low-income and middle-income households with high to medium density demography. From Table 5, the study has also shown that 40.2% of the total solid waste generated in Enugu metropolis was made of biodegradable matter while the rest 59.93% accounted for non-biodegradable matter. This suggests the need to have a disposal unit especially for non-biodegradable wastes in line with the 'Waste to Wealth' initiative and also to effectively enforce the 3 Rs of Reduce, Reuse and Recycle.

4. CONCLUSION

The characterization of solid waste in the south metropolis of Enugu has been researched. This is the primary step required for any community to achieve sustainable solid waste management. The first stage in solid waste management is to understand the waste kinds that are generated in order to establish appropriate collection and disposal methods, which can be accomplished through solid waste characterization. The majority of waste generated in Enugu metropolis can be composted rather than disposed away. Food/organic matter, glass/ceramics, metals (alum/iron), paper, plastics and rubber make up the majority of the solid waste produced. According to the study, biodegradable matter accounted for 40.16% of the total solid waste created in the Enugu south area, while non-biodegradable matter accounted for the remainder which is 59.93%. The study area's per capita trash generation ranged between 0.36 and 0.67 kg/capita/day. Using the results of this characterization study as a guide, the results clearly indicate the necessity to create formal composting (for 40.2% of the waste) and recycling facilities (for 59.93% of the waste) facilities within the Enugu urban region. Efforts should be made by stakeholders to develop and implement policies and strategies for disposal, waste reduction and recycling project. There is need for adequate budgetary provision for Enugu Environmental Protection Board, EEPB to invest in waste collection and disposal infrastructure for proper training and replacement of the existing vehicles with modern equipment to reduce operating costs. The agency should also encourage community participation and involvement in waste management. Furthermore, formal composting and recycling facilities should be setup at Enugu to promote waste segregation, composting and recycling, and also, establishment of a dumpsite.

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