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CHARACTERIZATION OF MUNICIPAL SOLID WASTE GENERATION AND MANAGEMENT PRACTICES IN AN OIL-EXPANDING URBAN CENTRE IN NIGERIA'S NIGER DELTA

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ABSTRACT

Municipal solid waste management remains a critical environmental challenge in rapidly urbanizing cities of developing countries, particularly in oil-producing regions where urbanization, industrialization, and changing consumption patterns intensify waste generation pressures. This study characterized solid waste generation, composition, and management practices in Warri Metropolis, Delta State, Nigeria. A mixed-methods approach was employed, combining household surveys (n=600), waste characterization studies (n=120 sampling points), key informant interviews (n=15), and focus group discussions (6 groups). Results revealed average daily waste generation of 0.82 kg per household (0.16 kg per capita), with organic/food waste constituting the dominant fraction (52.4%), followed by plastics (18.6%), paper (12.3%), glass (5.8%), and metals (4.2%). Waste collection services remain inadequate, with only 12.0% of households enjoying full coverage, 36.0% having no coverage, and 40.0% resorting to open dumping. Collection frequency is limited, with only 8.0% receiving daily collection, while 20.0% experience irregular schedules and 10.0% receive no collection services. The recycling rate remains extremely low at 4.0%, with 60.0% of households never recycling. The high organic content (52.4%) and substantial recyclable fraction (40.8%) indicate significant potential for composting and resource recovery. These findings demonstrate critical gaps in waste management infrastructure and services, highlighting opportunities for circular economy approaches and integrated waste management systems that can improve environmental sustainability and community well-being in Warri Metropolis.

KEYWORDS: Solid waste characterization; waste generation; waste management practices; organic waste; Warri Metropolis; Niger Delta.

1. INTRODUCTION

Municipal solid waste management has emerged as one of the most pressing environmental and public health challenges confronting urban centres globally, with particularly acute manifestations in rapidly urbanizing cities of developing countries (Kaza et al., 2018; Wilson et al., 2015). The intricate relationship between waste generation, disposal practices, environmental sustainability, and community well-being has garnered increasing attention from researchers, policymakers, and practitioners across multiple disciplines (UNEP, 2021; Ferreira et al., 2024). The World Bank estimates that global waste generation will increase from approximately 2.01 billion tonnes annually to 3.40 billion tonnes by 2050, with the most significant increases projected in Sub-Saharan Africa and South Asia (Kaza et al., 2018; Hoornweg&Bhada-Tata, 2012). This trajectory poses substantial challenges for environmental sustainability, as poorly managed waste contributes to greenhouse gas emissions, contamination of air, water, and soil resources, and degradation of ecosystems (Bogner et al., 2008; Wilson et al., 2015).

In developing countries, waste management systems are often characterized by inadequate collection services, limited recycling infrastructure, weak institutional capacity, and reliance on open dumping (Marshall &Farahbakhsh, 2013; Wilson et al., 2012). Collection rates typically range from 20% to 60% in Sub-Saharan African cities, with the poorest and most marginalized areas receiving the lowest level of service (Kaza et al., 2018). The composition of waste in developing countries differs significantly from that in developed countries, with a higher proportion of organic waste (typically 40-70%) and lower packaging waste, reflecting different consumption patterns and economic activities (Hoornweg&Bhada-Tata, 2012; Agamuthu, 2013). This high organic content presents both challenges and opportunities: it contributes to methane emissions in landfills while offering potential for composting and biogas generation (Agamuthu, 2013; Ayotamuno& Gobo, 2004).

Nigeria, as Africa's most populous country and largest economy, faces significant and escalating waste management challenges (Accountability Lab Nigeria, 2025; Ogwueleka, 2009). The country experiences rapid urbanization, with approximately 53% of the population residing in urban areas, projected to increase to 70% by 2050 (UN-Habitat, 2022). Nigeria generates approximately 32 million tonnes of waste annually, making it one of the highest waste-generating countries in Africa (Accountability Lab Nigeria, 2025). Waste collection services cover only 20-30% of generated waste, with uncollected waste often ending in open spaces, drains, and water bodies (Accountability Lab Nigeria, 2025). The country's recycling infrastructure remains underdeveloped, with less than 10% of plastic waste recycled, despite significant potential for resource recovery (Accountability Lab Nigeria, 2025). Institutional responsibilities for waste management in Nigeria are fragmented across multiple levels of government, with the National Environmental Standards and Regulations Enforcement Agency (NESREA) responsible for environmental regulation at the federal level, while state and local governments bear primary responsibility for waste collection and disposal (Ogwueleka, 2009; Nzeadibe, 2009).

Warri metropolis, located in the Niger Delta region of Delta State, Nigeria, exemplifies these waste management challenges while possessing distinctive local characteristics shaped by its role as a major centre of petroleum extraction, commerce, and transportation (Agee et al., 2024; Obru-Egboro& Eze, 2023). The metropolis has experienced rapid urbanization and population growth, with an estimated population of approximately 1.5 million people, driven by economic opportunities associated with petroleum and commercial activities. However, this growth has not been matched by adequate waste management infrastructure and services (Agee et al., 2024). Studies have documented the prevalence of indiscriminate waste disposal, with households disposing of waste in unauthorized locations due to poor waste management laws, lack of waste facilities, and household attitudes toward waste disposal (Agee et al., 2024). The absence of effective waste collection services in many areas has resulted in the proliferation of illegal dumpsites, creating environmental hazards and public health risks (Obru-Egboro& Eze, 2023).

The governance of waste management in Warri has been characterized by fragmented institutional responsibilities, weak enforcement, and inadequate funding (Ojevwe& Gabriel, 2025; Obru-Egboro& Eze, 2023). The Delta State Environmental Protection Agency (DELSEPA) has primary responsibility for waste management in the state, but its effectiveness has been constrained by resource limitations, organizational challenges, and weak enforcement capacity (Ojevwe& Gabriel, 2025). The environmental impacts of waste management practices in Warri are evident in soil contamination, air pollution, and water quality degradation (Ojevwe& Gabriel, 2025; Agbozu et al., 2020). Studies have documented elevated levels of heavy metals and organic pollutants in soils around waste disposal sites, with implications for ecosystem health and human exposure (Ojevwe& Gabriel, 2025).

Despite growing awareness of waste management challenges, there remains a significant gap in comprehensive characterization of waste generation and management practices in Warri metropolis. Previous studies have often examined these issues separately, with limited integration of waste characterization, governance, and community perspectives within a unified assessment framework (Agee et al., 2024; Ojevwe& Gabriel, 2025). Understanding the types and quantities of waste generated, current management practices, and the factors influencing waste disposal behavior is essential for developing effective waste management strategies (Tchobanoglous et al., 2022; Wilson et al., 2015). This study addresses this gap by providing a comprehensive characterization of municipal solid waste generation, composition, and management practices in Warri metropolis, grounded in empirical data collected through household surveys, waste characterization studies, and stakeholder engagement. The findings provide evidence for designing integrated waste management interventions that can improve environmental sustainability and community well-being in Warri and similar urban contexts in Nigeria and Sub-Saharan Africa.

2. METHODOLOGY

2.1 Study Area Description

Warri metropolis is located in Delta State, Nigeria, in the Niger Delta region of southern Nigeria, approximately at latitude 5°31′ N and longitude 5°45′ E, on the western bank of the Warri River (Agee et al., 2024). The metropolis encompasses Warri, Effurun, and surrounding areas, spanning Warri South, Warri North, Warri South-West, and Uvwie Local Government Areas. The area experiences a tropical monsoon climate characterized by high temperatures (25-29°C), high humidity (80-90%), and abundant rainfall (1,800-2,500 mm annually) with a wet season (April-October) and dry season (November-March). The metropolis has an estimated population of approximately 1.5 million people, with rapid growth driven by natural increase and rural-urban migration. The economy is dominated by petroleum extraction, commerce, and transportation, with significant contributions from trade, fishing, agriculture, and the informal sector.

2.2 Study Design and Sampling Framework

This study employed a mixed-methods research design combining quantitative household surveys, waste characterization studies, and qualitative stakeholder engagement (Creswell & Creswell, 2018; Flick, 2018). The quantitative component involved structured household questionnaires administered to 600 households selected through multistage stratified random sampling across the four local government areas. Sample size determination followed the Cochran formula (Cochran, 1977):

n=N1+N(e)2n=1+N(e)2N

Where:

- n = sample size
- N = population size (approximately 300,000 households)
- e = margin of error (0.05)

This yielded a sample of 399 households, which was increased to 600 to account for non-response and enhance statistical power (Hair et al., 2019). Stratification was based on settlement type (urban, peri-urban, informal), socio-economic status (low, medium, high income), and proximity to waste disposal facilities. Households were selected using systematic random sampling within each stratum.

The qualitative component comprised 15 key informant interviews with stakeholders from government agencies, environmental regulators, private waste management companies, and community leaders, selected through purposive sampling based on their involvement in waste management (Patton, 2015). Six focus group discussions were conducted with 8-10 participants each, selected to ensure diversity in age, gender, occupation, and community representation.

2.3 Waste Characterization Methodology

Waste characterization was conducted at 120 sampling points distributed across residential, commercial, and institutional areas of the metropolis, following standardized waste characterization protocols (Tchobanoglous et al., 2022; ASTM, 2020). The waste characterization involved:

Waste Composition Analysis: Waste samples were collected from households, markets, and commercial establishments, sorted into physical categories (organic/food waste, plastic, paper, glass, metal, textile, electronic waste, and others), weighed using calibrated scales, and expressed as percentages of total waste mass.

Waste Generation Rate: Average daily waste generation per household and per capita was calculated using:

$$WGpc = \frac{WGtotal}{HHsize}$$

Where:

- $WGpc$ = Per capita waste generation (kg/person/day)
- $WGtotal$ = Total household waste generated (kg/day)
- $HHsize$ = Household size

Waste Density: Waste density was determined by measuring the mass of waste per unit volume.

Recovery Potential: Resource recovery potential was assessed by identifying waste fractions suitable for recycling (plastic, paper, glass, metal, electronic), composting (organic waste), and energy recovery (combustible fractions).

2.4 Household Survey and Questionnaire Design

The structured household questionnaire contained 175 variables organized into six thematic modules: (1) household demographic and socio-economic characteristics, (2) waste generation patterns and sources, (3) waste storage and disposal practices, (4) access to and satisfaction with waste collection services, (5) recycling and composting behavior, and (6) community participation and environmental awareness. The questionnaire was pilot-tested with 50 households to assess clarity, comprehensiveness, and time requirements, with revisions made based on feedback.

2.5 Data Collection Procedures

Data collection was conducted between January and June 2026 by trained enumerators under the supervision of the research team. Field reconnaissance was conducted to familiarize enumerators with the study area and sampling locations. Household surveys were administered through face-to-face interviews using mobile data collection devices. Waste characterization was conducted at selected locations using standardized sorting and weighing procedures. Key informant interviews and focus group discussions were conducted using semi-structured guides, audio-recorded with participant consent, and transcribed verbatim for analysis.

2.6 Data Analysis

Quantitative data were analyzed using SPSS version 27 and Microsoft Excel. Descriptive statistics (frequencies, percentages, means, standard deviations) were calculated for all variables. Waste composition data were expressed as percentages of total waste mass and presented using charts and tables. Socio-demographic variables were cross-tabulated with waste management practices to identify patterns and relationships.

Qualitative data from key informant interviews and focus group discussions were analyzed using thematic analysis following the six-step framework of Braun and Clarke (2006): familiarization, coding, theme generation, review, definition, and writing. Key themes were identified and representative quotations selected to illustrate findings. The mixed-methods approach enabled triangulation of findings across quantitative and qualitative data sources, enhancing validity and reliability.

2.7 Ethical Considerations

Ethical approval was obtained from the Federal University of Petroleum Resources, Effurun, Research Ethics Committee. Informed consent was obtained from all participants prior to data collection, with assurance of confidentiality and anonymity. Participants were informed of their right to withdraw at any time without penalty. Data were stored securely and de-identified during analysis and reporting.

2.8 Quality Assurance

Quality assurance measures included: (1) standardization of data collection procedures through enumerator training and pilot testing; (2) validation of waste characterization results using multiple sampling points; (3) triangulation of household survey findings with key informant interviews and focus group discussions; (4) data screening for completeness and consistency; and (5) independent verification of a random sample of 10% of survey responses.

3. RESULTS

3.1 Socio-Demographic Characteristics of Respondents

Table 1: Socio-Demographic Characteristics of Respondents.

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	312	52.0
	Female	288	48.0
Age Group	18-25	102	17.0
	26-35	168	28.0
	36-45	144	24.0
	46-55	96	16.0
	56-65	54	9.0
	66+	36	6.0
Education	No formal education	36	6.0
	Primary school	78	13.0
	Secondary school	168	28.0
	Diploma/OND/NCE	120	20.0
	Bachelor's/HND	144	24.0
	Postgraduate	54	9.0
Occupation	Civil servant	84	14.0
	Private sector	120	20.0
	Business/trading	144	24.0
	Artisan/skilled worker	72	12.0
	Farmer/fisherman	48	8.0
	Unemployed	60	10.0
	Student	48	8.0
	Retired	24	4.0
Monthly Income	Less than ₦50,000	144	24.0

	₦50,000-100,000	168	28.0
	₦100,001-200,000	144	24.0
	₦200,001-300,000	84	14.0
	₦300,001-500,000	42	7.0
	Above ₦500,000	18	3.0
Household Size	1-3	120	20.0
	4-5	210	35.0
	6-7	150	25.0
	8-9	72	12.0
	10+	48	8.0
Length of Residence	Less than 1 year	36	6.0
	1-5 years	144	24.0
	6-10 years	156	26.0
	11-15 years	102	17.0
	More than 15 years	162	27.0

The socio-demographic characteristics of respondents (Table 1) show a relatively balanced gender distribution (52.0% male, 48.0% female) and a predominantly young population, with 69.0% aged between 18 and 45 years. Educational attainment is relatively high, with 53.0% having completed secondary school or higher. Occupational distribution reflects the commercial character of Warri, with business/trading (24.0%) and private sector employment (20.0%) being the most common occupations. Income distribution shows that 52.0% of households earn between ₦50,000 and ₦200,000 monthly, while 24.0% earn below ₦50,000. Average household size is 5.2 members, consistent with the national average for urban Nigeria. Length of residence data indicate population stability, with 70.0% having lived in Warri for 6 or more years.

Distribution of household survey respondents across different age groups in the study area.

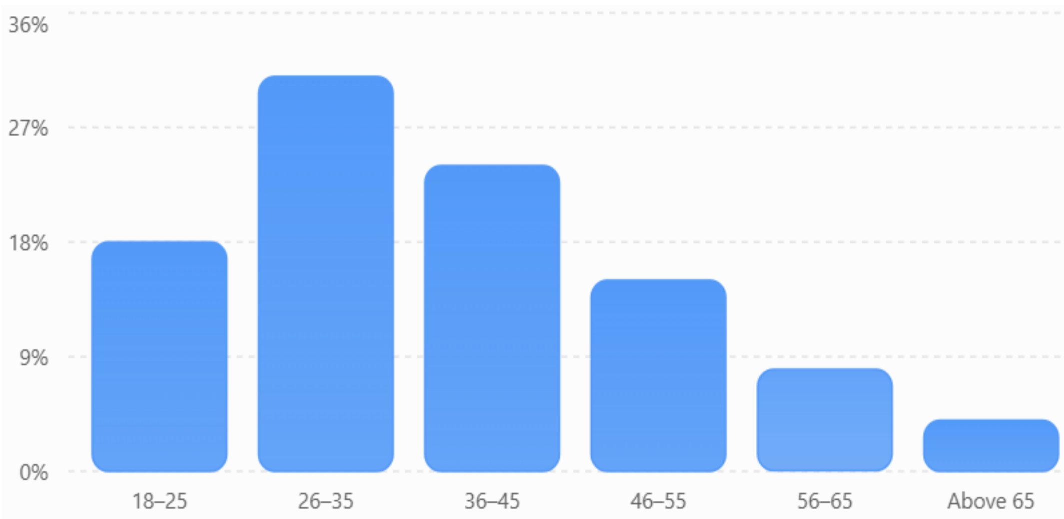

Figure 3.1: Age Distribution of Respondents.

[Bar chart showing age distribution with highest proportion in 26-35 age group (28%) and decreasing representation in older age groups]

Figure 1 shows that the **26-35 years** age group constitutes the largest proportion (31%), followed by the **36-45 years** group (24%), reflecting the predominance of economically active adults who are directly involved in waste generation and management activities in the study area.

3.2 Waste Generation Characteristics

Table 2: Types of Waste Generated by Households.

Waste Type	Households Generating Waste (n)	Percentage (%)
Organic/Food Waste	582	97.0
Plastic Waste	564	94.0
Paper Waste	498	83.0
Glass Waste	372	62.0
Metal Waste	348	58.0
Textile Waste	264	44.0
Electronic Waste	144	24.0
Other Waste	108	18.0

Table 2 shows that organic/food waste is generated by almost all households (97.0%), followed by plastic waste (94.0%) and paper waste (83.0%). Glass waste (62.0%) and metal waste (58.0%) are generated by a majority of households, while textile waste (44.0%) and electronic waste (24.0%) are generated by fewer households. The dominance of organic waste reflects consumption patterns based on fresh food and limited processed food, while the widespread generation of plastic waste reflects the prevalent use of plastics in packaging and consumer goods.

Table 3: Waste Generation Rates.

Parameter	Value
Average Daily Waste Generation per Household	0.82 kg
Average Daily Waste Generation per Capita	0.16 kg
Weekly Waste Generation per Household	5.74 kg
Monthly Waste Generation per Household	24.6 kg
Annual Waste Generation (Metropolis)	438,000 tonnes

Table 3 shows the average daily waste generation per household is 0.82 kg, translating to 0.16 kg per capita based on an average household size of 5.2 persons. This figure is lower than the Nigerian urban average of 0.5-0.6 kg/capita/day reported by Ogwueleka (2009), reflecting relatively lower income levels and the high proportion of organic waste which is

less dense than packaging waste. Annual waste generation for the metropolis is estimated at 438,000 tonnes, indicating substantial volumes requiring management.

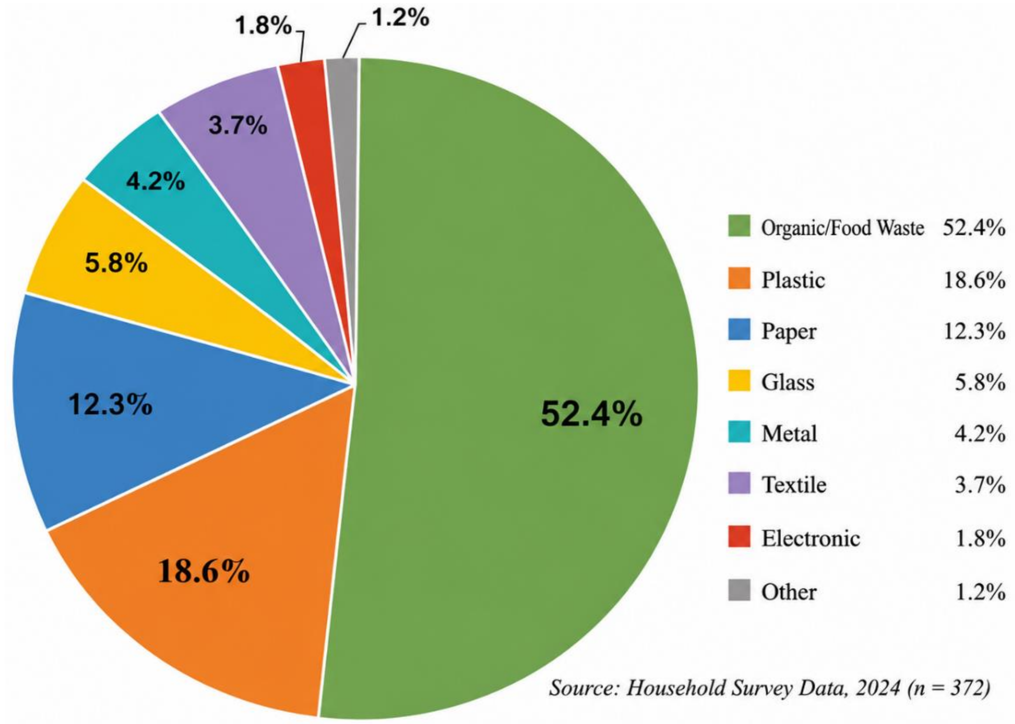

Figure 3.2: Waste Composition by Percentage.

[Pie chart showing: Organic/Food Waste 52.4%, Plastic 18.6%, Paper 12.3%, Glass 5.8%, Metal 4.2%, Textile 3.7%, Electronic 1.8%, Other 1.2%]

Figure 2 presents the composition of household waste, showing organic/food waste as the dominant component at 52.4%, followed by plastic waste at 18.6%, paper waste at 12.3%, glass at 5.8%, metal at 4.2%, textile at 3.7%, electronic at 1.8%, and other waste at 1.2%. The high organic content and substantial recyclable fraction (40.8%) indicate significant potential for resource recovery through composting and recycling, while the low proportion of electronic waste (1.8%) reflects limited consumption of electronics among the population.

Table 4: Waste Composition and Recovery Potential.

Waste Component	Percentage (%)	Recovery Potential	Recovery Method
Organic/Food Waste	52.4	High	Composting, Anaerobic Digestion
Plastic Waste	18.6	Medium	Recycling, Energy Recovery
Paper Waste	12.3	High	Recycling
Glass Waste	5.8	High	Recycling
Metal Waste	4.2	High	Recycling

Textile Waste	3.7	Medium	Recycling, Reuse
Electronic Waste	1.8	High	Recycling
Other Waste	1.2	Low	Disposal

Table 4 shows the recovery potential for each waste component. Organic waste (52.4%) has high potential for composting and anaerobic digestion, while paper (12.3%), glass (5.8%), and metal (4.2%) have high potential for recycling. Plastic (18.6%) has medium potential for recycling and energy recovery, while electronic waste (1.8%) has high potential for specialized recycling. The total recyclable fraction (40.8%) indicates significant resource recovery opportunities.

Household waste composition showing the percentage contribution of each waste component and its corresponding resource recovery pathway

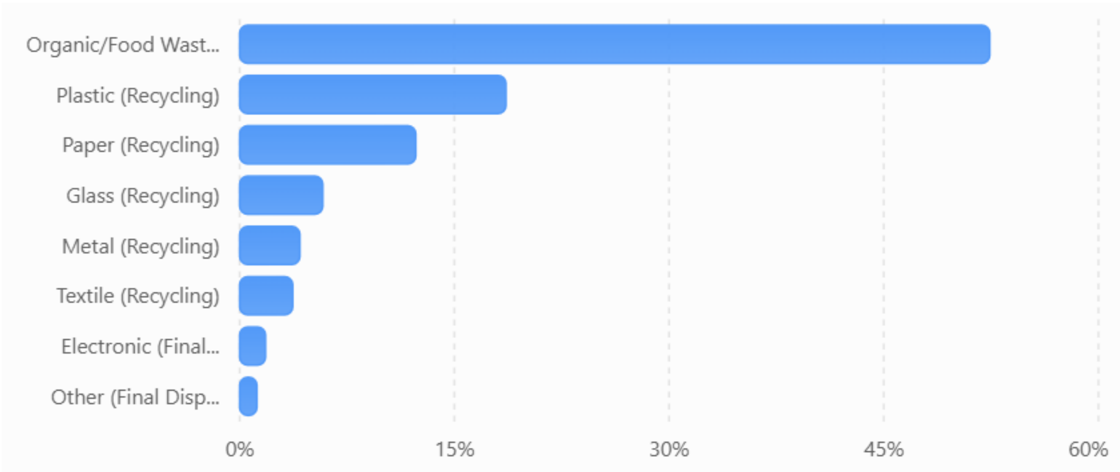

Figure 3.3: Waste Composition and Resource Recovery Potential.

[Bar chart showing waste components by percentage and recovery potential categories]

Figure 3.3 demonstrates that organic waste constitutes the largest component (52.4%), followed by plastic (18.6%) and paper (12.3%). Recovery potential analysis indicates that approximately 52.4% is suitable for biological treatment, 40.8% for recycling, and only 6.8% requiring final disposal. These findings demonstrate substantial opportunities for resource recovery, landfill diversion, and implementation of circular economy strategies.

3.3 Waste Management Practices

Table 5: Waste Storage Methods.

Storage Method	Frequency (n)	Percentage (%)
Covered Bins	144	24.0
Open Containers	192	32.0

Plastic Bags	168	28.0
Direct Ground Dumping	60	10.0
Other Methods	36	6.0

Table 5 shows that only 24.0% of households use covered bins for waste storage, while 32.0% use open containers, 28.0% use plastic bags, and 10.0% dump waste directly on the ground. The limited use of covered bins is concerning as it increases the risk of pest infestation, disease vector breeding, and disease transmission.

Table 6: Collection Frequency.

Collection Frequency	Frequency (n)	Percentage (%)
Daily	48	8.0
Twice Weekly	84	14.0
Weekly	132	22.0
Bi-weekly	96	16.0
Monthly	60	10.0
Irregular/No Schedule	120	20.0
No Collection	60	10.0

Table 6 shows that only 8.0% of households receive daily collection, while 14.0% receive twice-weekly collection, 22.0% receive weekly collection, and 16.0% receive bi-weekly collection. Critically, 10.0% receive no collection, and 20.0% experience irregular collection schedules. The limited collection frequency is a significant concern, leading to waste accumulation and increased risk of indiscriminate disposal.

Table 7: Collection Coverage and Reliability.

Collection Coverage	Frequency (n)	Percentage (%)
Full Coverage	72	12.0
Partial Coverage	312	52.0
No Coverage	216	36.0
Collection Reliability	Frequency (n)	Percentage (%)
Very Reliable	48	8.0
Reliable	132	22.0
Moderately Reliable	180	30.0
Unreliable	156	26.0
Very Unreliable	84	14.0

Table 7 reveals that only 12.0% of households have full collection coverage, 52.0% have partial coverage, and 36.0% have no coverage, representing a fundamental failure of the waste management system. Collection reliability is also poor, with only 30.0% rating it reliable or very reliable, while 40.0% rate it as unreliable or very unreliable. The low reliability erodes public confidence and may encourage indiscriminate disposal.

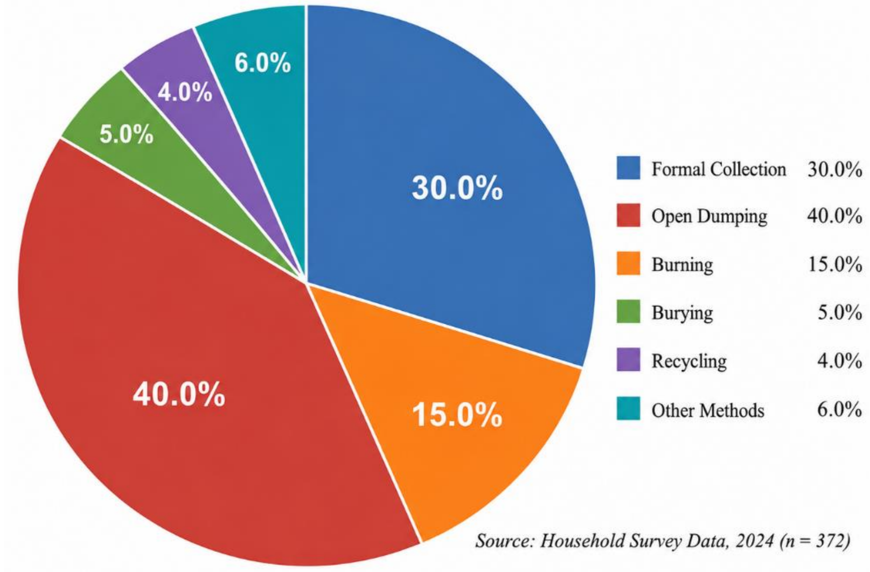

Figure 3.4: Current Disposal Methods.

Figure 3.4 presents the disposal methods used by households. Open dumping is the most common method at 40.0%, followed by formal collection at 30.0%, burning at 15.0%, burying at 5.0%, recycling at 4.0%, and other methods at 6.0%. The high proportion of open dumping and burning is concerning due to serious environmental and health implications, including air pollution, water contamination, soil degradation, and disease transmission.

Table 8: Recycling Practices.

Recycling Frequency	Frequency (n)	Percentage (%)
Never Recycle	360	60.0
Rarely Recycle	120	20.0
Sometimes Recycle	72	12.0
Frequently Recycle	30	5.0
Always Recycle	18	3.0

Table 8 shows that 60.0% of households never recycle, 20.0% rarely recycle, and only 8.0% frequently or always recycle. The extremely low recycling rate reflects limited recycling infrastructure, absence of incentives, and low awareness about the benefits of recycling. This represents a missed opportunity for resource recovery and environmental protection.

3.4 Governance and Community Participation

Table 9: Governance Quality Assessment.

Indicator	Mean Score (1-5)	Standard Deviation	Rank
Policy Framework	2.45	1.15	1
Institutional Clarity	2.34	1.12	2
Coordination Mechanisms	2.12	1.05	3

Resource Adequacy	1.98	0.95	4
Enforcement Effectiveness	1.87	0.92	5
Overall Governance Quality	**2.15**	**1.04**	

Table 9 shows low governance quality across all indicators (overall mean score of 2.15 out of 5). Policy framework scores highest (2.45) while enforcement effectiveness scores lowest (1.87), indicating that while policies exist, their implementation and enforcement are severely limited. These findings align with previous studies documenting fragmented responsibilities, weak enforcement, and inadequate funding as major constraints on waste management performance in Nigerian cities (Nzeadibe, 2009; Ogwueleka, 2009).

Table 10: Community Participation Assessment.

Indicator	Mean Score (1-5)	Standard Deviation	Rank
Willingness to Participate	2.56	1.15	1
Awareness Level	2.45	1.12	2
Satisfaction Level	2.34	1.08	3
Participation Rate	2.12	1.05	4
Community Engagement	2.12	1.05	5
Overall Community Participation	**2.32**	**1.09**	

Table 10 shows moderate community participation (overall mean score of 2.32 out of 5). Willingness to participate scores highest (2.56), suggesting untapped potential for community engagement, while participation rate and community engagement score lowest (2.12), indicating limited opportunities for actual participation. This gap between willingness and actual participation suggests structural barriers that require targeted interventions.

3.5 Qualitative Findings

Table 11: Key Informant Interview Themes.

Theme	Key Findings
Institutional Challenges	Fragmented responsibilities, poor coordination, limited capacity
Governance	Weak enforcement, political interference, inadequate accountability
Funding	Inadequate budgets, limited revenue collection, dependence on government
Infrastructure	Limited collection vehicles, poor roads, no engineered landfill
Policy	Outdated policies, limited enforcement, no incentives
Private Sector	Limited private sector engagement, inadequate regulation
Community Engagement	Limited public awareness, inadequate participation

Table 11 summarizes themes from key informant interviews. Informants reported fragmented institutional responsibilities, weak enforcement, and inadequate funding as persistent challenges. The absence of an engineered landfill and limited collection vehicles were identified as critical infrastructure gaps. Informants emphasized the need for integrated approaches, stakeholder engagement, and sustainable financing as priorities for improving waste management.

Focus Group Discussion Findings: Communities view waste management primarily as a government responsibility, with low satisfaction with services. Indiscriminate disposal is common, reflecting limited collection coverage. Communities report health problems related to waste, including malaria, diarrhoea, and respiratory diseases. Communities' express willingness to participate in waste management if services improve and awareness increases. These findings highlight the need for improved services, enforcement, awareness campaigns, and community involvement.

4. DISCUSSION

The findings of this study provide a comprehensive characterization of municipal solid waste generation and management practices in Warri Metropolis, revealing critical gaps in waste management infrastructure and services while identifying significant opportunities for resource recovery and sustainable waste management interventions.

4.1 Waste Generation and Composition

The average daily waste generation of 0.82 kg per household (0.16 kg per capita) is notably lower than the typical Nigerian urban average range. This difference reflects the relatively lower income levels of respondents in this study (with 52.0% earning between ₦50,000 and ₦200,000 monthly) and the high proportion of organic waste (52.4%), which is less dense than packaging waste. The lower generation rate, however, should not be interpreted as a positive indicator, as it may reflect poverty and limited consumption rather than sustainable waste management practices. As economic development proceeds and consumption patterns change, waste generation rates are likely to increase, making it imperative that sustainable waste management systems are developed now to accommodate future growth.

The dominance of organic waste (52.4%) is a defining feature of the waste composition with profound implications for waste management planning. This high organic content is consistent with waste characterization studies conducted across various Nigerian urban centers and reflects consumption patterns based on fresh food, limited processed food, and traditional food preparation practices. The high organic content suggests that composting and anaerobic digestion are potentially viable and appropriate waste treatment options that could significantly reduce the volume of waste requiring disposal while generating valuable products such as compost for agriculture and biogas for energy generation. However, the organic waste also presents challenges, as it decomposes rapidly, generating methane and other greenhouse gases when disposed of in landfills, and creating leachate that can contaminate water resources if not properly managed.

The plastic waste component (18.6%) is the second largest category and reflects the widespread use of plastics in packaging and consumer goods that has accompanied urbanization and economic development. The high plastic content presents particular challenges, as plastics are non-biodegradable, contribute to visual pollution, and can persist in the environment for centuries. The low recycling rate for plastics (less than 10% of plastic waste is recycled) represents a missed opportunity for resource recovery and a significant environmental burden contributing to plastic pollution of water bodies and ecosystems. The presence of paper waste (12.3%) and glass waste (5.8%) indicates opportunities for recycling, while metal waste (4.2%) and electronic waste (1.8%) suggest potential for resource recovery, though the latter requires specialized handling due to hazardous components.

The substantial recyclable fraction (40.8%) represents a significant opportunity for resource recovery and circular economy transition. This finding aligns with the circular economy paradigm, which aims to keep materials in use for as long as possible and minimize waste generation. The transition from linear to circular approaches could create employment opportunities in recycling and remanufacturing, reduce dependence on imported materials, and address pressing environmental challenges. In the Nigerian context, the informal sector already plays a significant role in waste recovery, and formalizing and supporting this sector could enhance recycling rates while improving livelihoods.

4.2 Waste Collection Services

The finding that only 12.0% of households have full collection coverage, while 36.0% have no coverage, represents a fundamental failure of the waste management system to provide essential services. The limited coverage reflects inadequate resources, capacity, and planning of waste management agencies, and prioritization of services to areas that are politically influential or economically viable, while peri-urban and low-income areas are neglected. This spatial inequity in service provision has implications for environmental justice, as communities with the fewest resources bear the greatest environmental burden.

The low collection frequency (only 8.0% receiving daily collection, 22.0% weekly) and poor reliability (only 30.0% rating services reliable) exacerbate waste management challenges by leading to accumulation of waste in neighborhoods and the proliferation of illegal dumping. The irregular collection schedules reported by 20.0% of households indicate operational challenges, including inadequate vehicle maintenance, fuel shortages, and poor planning, that undermine service reliability. The low collection reliability erodes public confidence in waste management authorities and may encourage households to seek alternative, often inappropriate, disposal methods.

The high proportion of open dumping (40.0%) and burning (15.0%) is particularly concerning due to serious environmental and health implications. Open dumping contributes to air pollution through the release of particulate matter and toxic gases from decomposition and burning, water contamination through leachate, and soil degradation through accumulation of waste and hazardous substances. Burning of waste releases toxic pollutants including dioxins, furans, and heavy metals that pose significant risks to respiratory health. The proximity of dumpsites to residential areas and water sources exacerbates these risks, creating environmental health burdens for communities.

4.3 Governance and Institutional Factors

The low governance quality (overall mean score of 2.15 out of 5) reflects fundamental weaknesses in the institutional framework for waste management. The fragmented responsibilities, weak enforcement, and limited funding documented in this study are consistent with findings from other Nigerian urban centers and reflect the limited political priority given to waste management. The key informant interviews revealed that institutional fragmentation, where multiple agencies share responsibility without clear coordination mechanisms, creates confusion, duplication of effort, and gaps in service delivery. The weak enforcement of environmental regulations reflects limited capacity, political interference, and absence of accountability mechanisms.

The finding that policy framework scores highest (2.45) while enforcement scores lowest (1.87) indicates that while policies exist, their implementation and enforcement are severely limited. This implementation gap is a critical barrier to effective waste management, highlighting the need to strengthen enforcement capacity, including increased funding, enhanced staffing, and improved technical skills. The clarification of institutional responsibilities, establishment of effective coordination mechanisms, and development of comprehensive waste management policies that address all aspects of waste management are essential for improving governance quality.

The moderate community participation (overall mean score of 2.32 out of 5) reflects limited awareness and opportunities for engagement. The finding that willingness to participate is higher than actual participation (2.56 vs. 2.12) suggests there is untapped potential for community engagement that could be mobilized through appropriate interventions. Focus group discussions revealed that communities are willing to participate if services improve and awareness increases, indicating that current low participation reflects structural barriers rather than a lack of community interest. This highlights the need for awareness campaigns, creation of participation opportunities, and building of trust between communities and waste management authorities to sustain community engagement.

4.4 Policy and Practical Implications

The findings have significant implications for waste management policy and practice. The limited collection coverage and frequency suggest the need for significant investment in collection infrastructure, including vehicles, equipment, and personnel, and development of a comprehensive collection strategy covering all areas with appropriate collection frequencies. The high organic content and low recycling rate suggest the need for investment in recycling and composting infrastructure, including material recovery facilities and composting plants. The reliance on open dumping suggests the need for development of sanitary landfills with environmental controls and closure of open dumpsites.

The governance challenges suggest the need for institutional strengthening, including clear definition of responsibilities, enhanced enforcement, and improved coordination. The limited community participation suggests the need for awareness campaigns, creation of participation opportunities, and building of trust between communities and waste management authorities. The high organic content and substantial recyclable fraction suggest opportunities for circular economy approaches, including composting, recycling, and resource recovery.

4.5 Limitations and Future Research

This study has several limitations that should be considered when interpreting findings. The cross-sectional design provides a snapshot at a single point in time and may not capture seasonal variations in waste generation and management. The reliance on self-reported data from household surveys may be subject to recall and social desirability bias. The focus on municipal solid waste excludes industrial, hazardous, and medical waste, which may also contribute to environmental contamination. Future research should employ longitudinal designs to track changes over time, and include industrial and hazardous waste streams in comprehensive waste management assessments. Studies should also examine the economic viability of different waste management options and the effectiveness of specific interventions, including recycling and composting programs.

4.6 Novel Contributions

This study makes several novel contributions to knowledge. First, it provides comprehensive characterization of waste generation and management practices in Warri Metropolis, establishing baseline data for waste management planning. Second, it identifies the high organic content (52.4%) and substantial recyclable fraction (40.8%) as opportunities for resource recovery and circular economy transition. Third, it documents critical gaps in collection coverage (36.0% no coverage), collection frequency (only 8.0% daily), and disposal practices (40.0% open dumping). Fourth, it reveals low governance quality (mean score 2.15 out of 5) and limited community participation (mean score 2.32 out of 5) as key constraints on waste management performance. Fifth, it provides empirical evidence for designing integrated waste management interventions that address collection, recycling, and disposal while strengthening governance and community participation.

4.7 CONCLUSION

In conclusion, this study demonstrates that municipal solid waste management in Warri Metropolis is characterized by inadequate services, reliance on open dumping, low recycling rates, weak governance, and limited community participation. The high organic content and substantial recyclable fraction indicate significant opportunities for resource recovery through composting and recycling. The findings highlight the urgent need for investment in waste management infrastructure, strengthening of institutional capacity, and engagement of communities in waste management. The transition to sustainable waste management in Warri requires integrated approaches that address all aspects of the waste management value chain, from generation to disposal, while promoting circular economy principles and protecting environmental quality and community well-being.

5. Key Findings Summary

Waste Generation:

- Average daily waste generation of 0.82 kg per household (0.16 kg per capita)
- Annual waste generation estimated at 438,000 tonnes
- Organic waste is the dominant component (52.4%), followed by plastic (18.6%) and paper (12.3%)

Waste Composition:

- Organic/food waste (52.4%)
- Plastic waste (18.6%)

- Paper waste (12.3%)
- Glass waste (5.8%)
- Metal waste (4.2%)
- Total recyclable fraction: 40.8%
- High resource recovery potential through composting and recycling

Waste Collection Services:

- Only 12.0% of households have full collection coverage
- 36.0% have no collection coverage
- Only 8.0% receive daily collection
- 20.0% experience irregular collection schedules
- Only 30.0% rate collection services as reliable

Waste Disposal Practices:

- Open dumping: 40.0% of households
- Formal collection: 30.0%
- Burning: 15.0%
- Burying: 5.0%
- Recycling: 4.0%

Recycling and Resource Recovery:

- 60.0% of households never recycle
- Only 8.0% frequently or always recycle
- High recovery potential: 52.4% for composting, 40.8% for recycling

Governance Quality:

- Overall mean score: 2.15 out of 5 (low governance quality)
- Highest score: Policy Framework (2.45)
- Lowest score: Enforcement Effectiveness (1.87)
- Fragmented institutional responsibilities and weak enforcement identified

Community Participation:

- Overall mean score: 2.32 out of 5 (moderate participation)
- Willingness to participate (2.56) exceeds actual participation (2.12)
- Limited awareness and opportunities for engagement identified

Qualitative Findings:

- Institutional fragmentation and weak governance constrain performance
- Communities express willingness to participate if services improve
- Health problems (malaria, diarrhoea, respiratory diseases) associated with waste

Key Opportunities:

- High organic content (52.4%) suitable for composting and biogas generation
- Substantial recyclable fraction (40.8%) for resource recovery
- Untapped potential for community participation
- Opportunities for integrated waste management systems

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