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ASSESSMENT OF HOUSEHOLD FOOD WASTE AS A POTENTIAL FEEDSTOCK FOR DECENTRALISED BIOENERGY PRODUCTION IN OKUOKOKO, DELTA STATE, NIGERIA

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Abstract

Household food waste poses persistent environmental challenges in rapidly urbanising communities, yet its relevance to decentralised bioenergy systems is rarely integrated into environmental assessments. This study examined food waste generation patterns, handling practices, and infrastructural conditions in Okuokoko, Delta State, Nigeria. Data were collected using a structured questionnaire administered to 250 households and analysed using descriptive statistics and reliability testing. Results indicate that 77.2% of households generate food waste daily, reflecting a temporally stable organic waste stream. Food waste generation is driven mainly by preparation-related losses (48.4%), followed by over-preparation (22.4%), weather-related spoilage (16.0%), and over-buying (8.8%). Disposal practices are predominantly unsustainable, with 57.2% of households using open dumpsites and 30.8% practising open dumping, while only 47.6% utilise waste collection services. Infrastructure constraints are evident, as 48.8% lack access to approved dumpsites. Although 58.0% report general waste management awareness, only 49.2% recognise food waste recycling, indicating a significant awareness gap.

Keywords: Food waste; Bioenergy potential; Environmental monitoring; Waste-to-energy; Anaerobic digestion; Urban waste management

1.0.Introduction

Rapid urbanisation, dietary transitions, and changing household consumption patterns have led to a marked increase in food waste generation in many low- and middle-income countries, intensifying pressure on already fragile waste management systems (UNEP, 2021; Kaza *et al.*, 2022). Food waste is environmentally significant due to its high biodegradability, which accelerates methane formation when unmanaged and contributes to local air quality degradation, odour nuisance, and public health risks (IPCC, 2021; Paolini *et al.*, 2022). Despite these impacts, food waste is still predominantly assessed within environmental monitoring frameworks as a sanitation and disposal challenge, with limited consideration of its embedded energy value.

Recent advances in environmental assessment have emphasised the need for integrated approaches that link waste characterisation, handling practices, and infrastructure with emission pathways and resource efficiency outcomes (Bennich *et al.*, 2022; OECD, 2023). Such integration is particularly relevant for organic waste streams, where management choices strongly influence greenhouse gas emissions and energy recovery potential (Serrano *et al.*, 2022; Li *et al.*, 2023). In peri-urban and informal urban settings, these dynamics are further shaped by limited institutional capacity and reliance on disposal-oriented practices (Wilson *et al.*, 2021).

Decentralised waste-to-energy systems, especially anaerobic digestion, have been increasingly identified as suitable options for managing household food waste in contexts characterised by dispersed generation and weak centralised infrastructure (Cudjoe *et al.*, 2023; Slorach *et al.*, 2022). However, the environmental performance of such systems depends critically on feedstock availability, temporal stability of waste generation, storage practices, and social acceptance, all of which must be evaluated at the community scale (Edjabou *et al.*, 2021; Bouman *et al.*, 2021).

In Nigeria, empirical studies that explicitly connect household food waste generation patterns with environmental monitoring indicators and energy recovery considerations remain limited. Existing research often focuses on waste quantities, awareness levels, or policy gaps in isolation, without examining how daily handling practices and infrastructural constraints shape environmental outcomes and resource efficiency (Ogwueleka, 2020; Akinbile *et al.*, 2021). This gap constrains the development of evidence-based strategies that align waste management with climate and energy objectives.

Against this background, the present study assesses household food waste generation, handling practices, and associated infrastructural and behavioural factors in Okuokoko, Delta State, Nigeria. Specifically, this study aims to assess household food

waste generation patterns and management practices in Okuokoko, Delta State, Nigeria, with a view to understanding how waste characteristics and prevailing disposal pathways shape environmental outcomes in settings characterised by rapid urbanisation and infrastructural constraints. By situating household-level practices within their broader environmental and institutional context, the study provides evidence relevant for strengthening environmental assessment and waste management decision-making in similar urbanising communities.

2.0 Materials and Methods

2.1 Study Area

The study was conducted in Okuokoko community, Uvwie Local Government Area, Delta State, Nigeria. Okuokoko is a peri-urban settlement experiencing rapid population growth, informal housing expansion, and increasing pressure on basic waste management services. Such settlements are widely recognised as critical zones for environmental monitoring studies because waste generation patterns, disposal behaviours, and infrastructural limitations interact strongly to influence environmental risk pathways (Wilson *et al.*, 2022; UN-Habitat, 2023). The predominance of household-level waste generation and limited formal treatment facilities make Okuokoko an appropriate case study for assessing food waste characteristics and their implications for environmental performance and decentralised resource recovery.

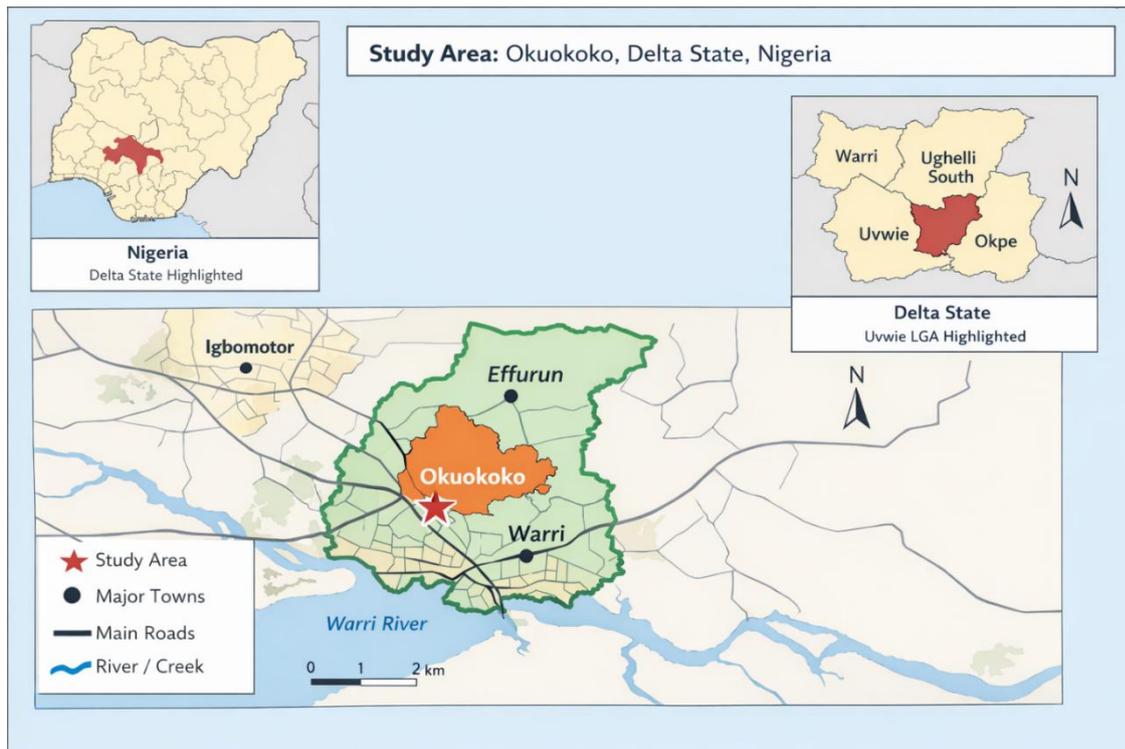


Plate 1: Map of Okuokoko, Delta State, Nigeria as the study area for this study

2.2 Study Design

A cross-sectional survey design was adopted to capture prevailing household food waste generation patterns, handling practices, infrastructural accessibility, and environmental awareness at a single point in time. Cross-sectional designs are widely applied in environmental assessment studies to characterise dominant conditions and behavioural trends where longitudinal data are unavailable (Seto *et al.*, 2021; OECD, 2023). This design is consistent with EMA's emphasis on observational assessment of environmental systems rather than experimental intervention.

2.3 Sampling Strategy and Sample Size

The study population comprised households within Okuokoko community. A simple random sampling technique was employed to ensure equal probability of selection and to minimise selection bias. Random household sampling is considered appropriate for community-scale waste characterisation and environmental exposure assessments (Edjabou *et al.*, 2021; Kaza *et al.*, 2022). Sample size was determined using a standard population proportion formula at a 90% confidence level and a 5% margin of error,

consistent with approaches used in urban environmental monitoring studies (UNEP, 2021). A total of 272 questionnaires were distributed, of which 250 were valid and included in the analysis. This sample size is sufficient to capture variability in household waste practices and support descriptive statistical interpretation at the community scale.

2.4 Data Collection Instrument

Data were collected using a structured questionnaire designed to capture variables directly relevant to food waste as an environmental and resource management issue. The questionnaire was organised into five sections:

- (i) socio-demographic characteristics,
- (ii) frequency and drivers of food waste generation,
- (iii) storage and disposal practices,
- (iv) access to waste infrastructure and services, and
- (v) environmental awareness and perceived health impacts.

Structured questionnaires are widely used in environmental waste studies to ensure consistency, comparability, and suitability for quantitative analysis, particularly where

direct waste weighing is impractical (van der Werf & Gilliland, 2021; Slorach *et al.*, 2022). The focus on household practices reflects evidence that domestic food waste constitutes a major fraction of organic waste in urban settings (UNEP, 2021).

2.5 Data Analysis

Data were coded and analysed using descriptive statistics, including frequencies and percentages, to characterise dominant waste generation patterns, handling practices, and infrastructural constraints. Descriptive analysis is appropriate for environmental monitoring studies where the objective is to identify prevailing conditions and system inefficiencies rather than to predict outcomes (Bennich *et al.*, 2022).

Results were presented using tables and figures to facilitate transparent interpretation and direct linkage between waste generation characteristics and environmental implications. To assess the internal consistency of perception- and awareness-based variables, reliability analysis was conducted using Cronbach's alpha. Reliability testing is recommended for survey-based environmental assessments to ensure interpretive robustness of behavioural indicators (Hair *et al.*, 2022; Boateng *et al.*, 2023).

2.6 Ethical Considerations and Data Quality Assurance

Participation in the survey was voluntary, and respondents were informed of the purpose of the study prior to data collection. No personal identifiers were collected, and responses were treated confidentially. Questionnaire pre-testing was conducted to improve clarity and reduce response bias. Data quality assurance measures included consistency checks during data entry and exclusion of incomplete responses. Such procedures are consistent with best practice for environmental and social data collection in community-scale assessments (UN-Habitat, 2023; OECD, 2023).

3.0 Results: Food Waste as Bioenergy Feedstock in Okuokoko

3.1 Socio-Economic Context for Household-Scale Bioenergy Generation

The socio-demographic characteristics of respondents are summarised in **Table 1**. The results show a predominantly economically active population, with household sizes largely within the range of 5–6 persons and extended residential stability in the community. These characteristics are relevant for decentralised bioenergy systems, as household size and daily cooking practices directly influence the quantity and regularity of food waste generation (Paritosh *et al.*, 2020; Zhang *et al.*, 2021).

Table 1. Socio-Demographic Characteristics of Respondents (n = 250)

Parameter	Category	Percentage (%)
Gender	Male	44.4
	Female	40.4
Age group	18–25 years	33.2
	26–30 years	24.0
	31–40 years	23.6
	≥41 years	15.6
Education level	Secondary education	36.8
	University education	32.0
Occupation	Self-employed	36.0
	Unemployed	27.2
Household size	5–6 persons	22.4
Length of residence	1–10 years	55.6

The dominance of self-employment and informal economic activities further implies sustained household food preparation, thereby ensuring a continuous supply of biodegradable organic waste suitable for small-scale anaerobic digestion systems (Kumar *et al.*, 2022).

3.2 Availability and Temporal Stability of Food Waste Feedstock

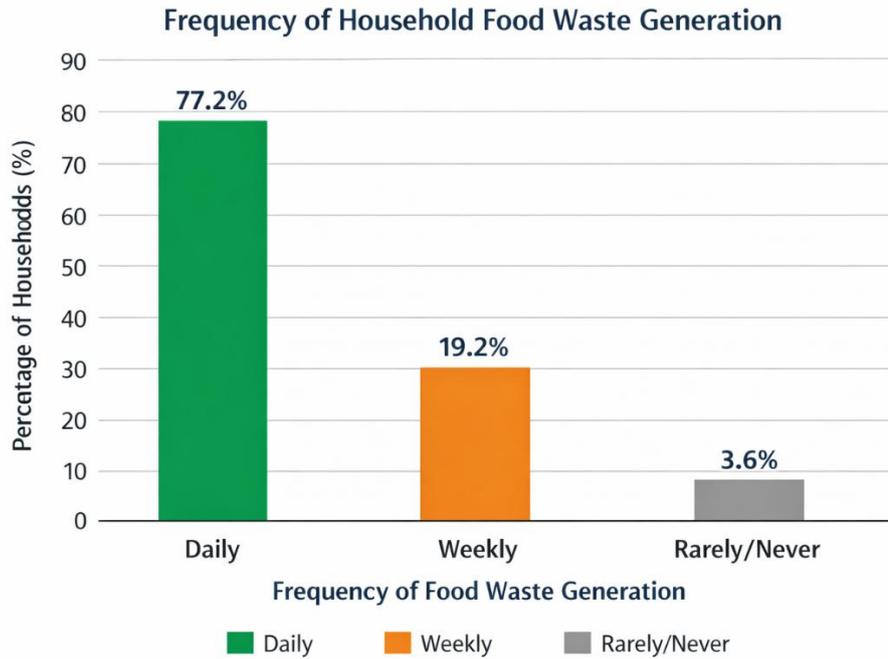
Household food waste generation in Okuokoko is predominantly regular and predictable. As shown in Table 2 and visually reinforced in Figure 1, 77.2% of households generate food waste daily, while 19.2% generate food waste on a weekly basis, indicating a temporally stable organic waste stream suitable for continuous bioenergy feedstock supply.

Table 2. Frequency and Drivers of Food Waste Generation

Indicator	Category	Percentage (%)
Frequency of food waste generation	Daily	77.2
	Weekly	19.2
Main drivers of food waste	Preparation errors (burning/spoilage)	48.4
	Over-preparation	22.4
	Weather-related spoilage	16.0
	Over-buying	8.8

The major drivers of food waste generation are quantitatively distributed across four categories. Preparation-related losses, including burning and spoilage during cooking, constitute the dominant source (48.4%). This is followed by over-preparation of meals (22.4%), weather-related spoilage (16.0%), and over-buying of food items (8.8%).

These waste fractions are largely composed of readily biodegradable organic materials, which are favourable for anaerobic digestion processes (Paritosh *et al.*, 2020; Kumar *et al.*, 2023). The dominance of preparation-related losses and over-preparation indicates that food waste generation is structurally embedded in routine household cooking practices rather than sporadic consumption behaviour.



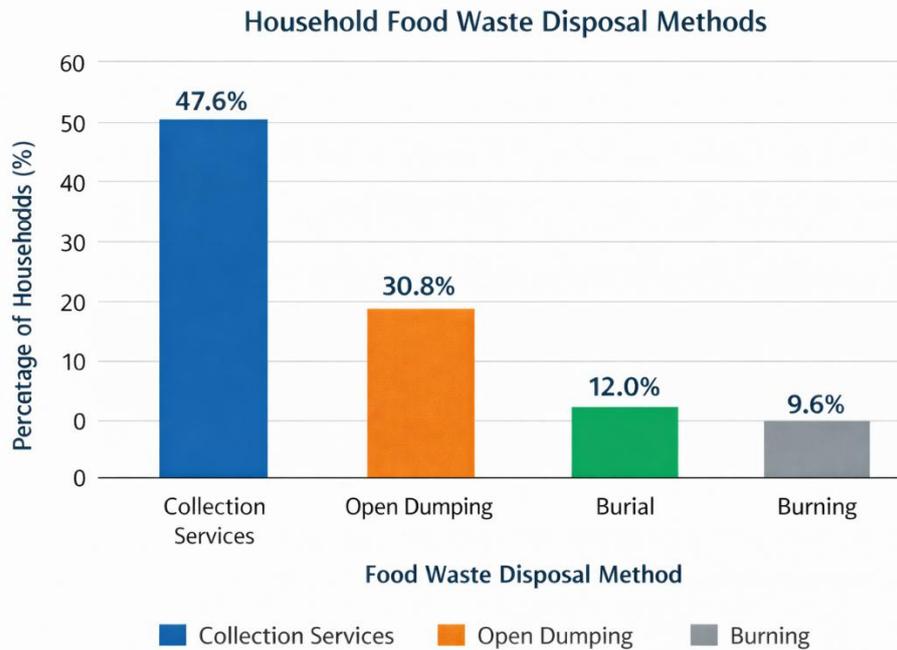
3.3. Waste Handling Practices and Loss of Bioenergy Potential

Food waste handling practices in the study area are predominantly disposal-oriented (Figure 2). As presented in Table 3, 40.8% of households temporarily store food waste in waste bins or baskets, while 37.2% use nylon bags. Storage duration is typically prolonged, with 36.4% of households retaining food waste for 2–3 days prior to disposal.

Table 3. Food Waste Storage and Disposal Pathways

Parameter	Dominant practice	Percentage (%)
Temporary storage	Waste bins/baskets	40.8
	Nylon bags	37.2
Storage duration	2–3 days	36.4
Disposal location	Open dumpsites	57.2
Disposal method	Collection services	47.6
	Open dumping	30.8

Regarding disposal pathways, 57.2% of respondents dispose of food waste at open dumpsites, while 30.8% practice direct open dumping. Although 47.6% of households utilise waste collection services, these services are largely unsegregated and focused on final disposal rather than resource recovery.



The extended storage period and dominance of open dumping promote uncontrolled anaerobic decomposition, resulting in methane emissions without energy capture and a loss of recoverable bioenergy potential.

3.4 Waste Infrastructure Constraints and Implications for Decentralised Bioenergy Systems

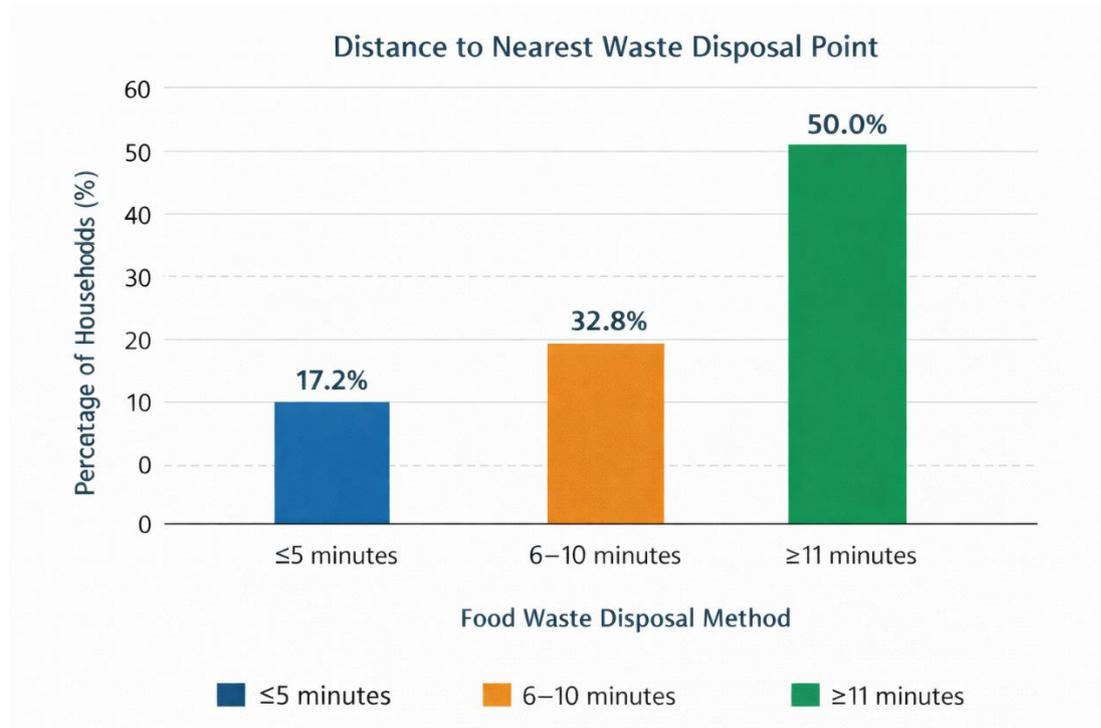
Waste management infrastructure within Okuokoko is limited and unevenly distributed. As shown in Table 4, 48.8% of respondents reported the absence of approved dumpsites or communal waste bins within their locality. In addition, 50.0% of households require more than 10 minutes to access the nearest disposal point.

Table 4. Waste Infrastructure and Accessibility

Indicator	Response	Percentage (%)
Availability of approved dumpsite	No	48.8
Distance to nearest dumpsite	≥11 minutes	50.0
Waste separation practiced	No	49.2
Presence of waste collection agency	Yes	45.6

Waste segregation practices are weak, with 49.2% of households reporting no form of waste separation, while only 45.6% indicated the presence of a formal waste collection agency. These infrastructural constraints discourage efficient waste aggregation and

favour decentralised treatment options that minimise transport and handling requirements. Accessibility challenges are further highlighted in **Figure 3**, where over 50% of households require more than 10 minutes to reach the nearest disposal point.



Such infrastructural limitations increase transportation burdens, encourage indiscriminate dumping, and undermine efficient waste aggregation.

These conditions strongly favour decentralised bioenergy systems, such as household- or community-scale anaerobic digesters, which reduce transport-related energy losses and enable on-site conversion of food waste into usable energy (Paritosh *et al.*, 2020; Kumar *et al.*, 2022).

3.5 Environmental Awareness and Social Readiness for Bioenergy Adoption

Environmental awareness among respondents shows mixed outcomes. As shown in Table 5, 58.0% of households reported awareness of general waste management practices, and 80.8% actively participate in sanitation or clean-up activities, only 49.2% were aware that food waste could be recycled or valorised.

Knowledge of institutional frameworks remains limited, as 64.0% of respondents reported no awareness of Delta State waste management policies. This awareness gap suggests that while pro-environmental behaviour exists, targeted education is required to support acceptance of food-waste-to-energy initiatives

Table 5. Environmental Awareness and Policy Knowledge

Indicator	Response	Percentage (%)
Awareness of waste management	Yes	58.0
Participation in sanitation activities	Yes	80.8
Awareness of food waste recycling	Yes	49.2
Knowledge of state waste policy	No	64.0

This awareness–practice gap is consistent with previous findings that social acceptance of waste-to-energy technologies depends on targeted education and institutional support

rather than general environmental concern alone (van der Werf *et al.*, 2021; Kaza *et al.*, 2022). Nonetheless, the high participation in sanitation activities suggests favourable

conditions for introducing food-waste-to-energy initiatives through community-based engagement.

3.6 Health and Environmental Co-Benefits of Food-Waste-Based Bioenergy

The health and environmental implications of prevailing household food waste management practices are summarised in Table 6. A substantial proportion of households (31.2%) reported experiencing waste-related illnesses within the recent period, indicating a non-trivial public health burden associated with current disposal practices. This finding suggests persistent exposure to environmental risk factors commonly linked to unmanaged organic

waste, particularly in densely populated peri-urban settings.

In addition, respondents identified multiple environmental nuisances associated with nearby dumpsites. The most frequently reported problems were offensive odour and exposed waste materials, reported by 32.4% of households. Such conditions are symptomatic of uncontrolled organic waste decomposition and are known to encourage vector proliferation, including rodents and insects, thereby exacerbating health risks. Despite these challenges, just over half of respondents (50.8%) perceived the overall environmental condition of their surroundings as *good to normal*, reflecting a possible normalisation of degraded environmental conditions or limited awareness of long-term health implications.

Table 6. Health and Environmental Impacts of Current Waste Practices

Indicator	Dominant outcome	Percentage (%)
Household disease occurrence	Yes	31.2
Common dumpsite problems	Odour / exposed waste	32.4
Perceived environmental condition	Good–Normal	50.8

Taken together, these results indicate that while acute waste-related health and environmental impacts are already evident, their perceived severity may be underestimated at the household level. The observed disease prevalence and environmental nuisances underscore the risks associated with disposal-oriented food waste management systems. In contrast, controlled anaerobic digestion of food waste has been shown to reduce sanitation-related health risks by limiting uncontrolled decomposition while simultaneously capturing methane for productive energy use, thereby contributing to climate change mitigation and improved environmental quality (Mata-Alvarez *et al.*, 2020; Li *et al.*, 2023).

3.7 Reliability of Data for Bioenergy Feasibility Assessment

The internal consistency of the survey instrument was assessed using Cronbach’s alpha to evaluate the reliability of behavioural and perception-based items. The results of this analysis are presented in Table 7. The instrument comprised 16 items, yielding an initial Cronbach’s alpha value of 0.559, which indicates moderate internal consistency. Following scale refinement and adjustment, the reliability coefficient increased to an adjusted Cronbach’s alpha of 0.787, meeting the threshold for acceptable reliability in social and environmental research

Table 7. Reliability and Statistical Validation of Survey Instrument

Parameter	Value
Number of items	16
Cronbach's alpha	0.559
Adjusted Cronbach's alpha	0.787
Reliability interpretation	Acceptable

An adjusted alpha value above 0.70 is widely regarded as indicative of satisfactory internal consistency, particularly for exploratory and perception-based survey instruments (Hair et al., 2022). The improvement in reliability after adjustment suggests that the retained items measure a coherent underlying construct related to household waste management behaviours and perceptions. Overall, this level of internal consistency supports the robustness of the dataset and confirms its suitability for interpreting household food waste practices and their implications for waste management assessment within the study area.

4.0 Discussion

4.1. Food Waste Availability and Implications for Bioenergy Feasibility

The results demonstrate that household food waste generation in Okuokoko is both frequent and predictable, with daily generation dominating across households. From an energy systems perspective, this temporal consistency is a critical determinant of feasibility, as bioenergy technologies—particularly anaerobic digestion—require stable organic inputs to sustain microbial activity and methane production. Similar studies across urban and peri-urban settings have shown that household-derived food waste, when generated daily and in sufficient volumes, constitutes a reliable feedstock for decentralised energy recovery systems (Edjabou *et al.*, 2021; Slorach *et al.*, 2022).

The dominance of preparation-related losses and over-preparation further strengthens the suitability of the waste stream for energy conversion. Such waste fractions are typically characterised by high moisture content and readily biodegradable carbohydrates, which have been shown to enhance biogas yields relative to mixed municipal waste streams (Fang *et al.*, 2021).

In this context, the results from Okuokoko align with broader evidence suggesting that household food waste represents one of the most energy-efficient organic substrates for small-scale bioenergy production in developing urban environments.

4.2. Energy Losses Embedded in Current Waste Handling Practices

Despite the demonstrated availability of suitable feedstock, current waste handling and disposal practices in Okuokoko reflect a predominantly linear waste management model. Temporary storage of food waste for several days prior to disposal promotes uncontrolled anaerobic decomposition, leading to diffuse methane emissions without energy recovery. This finding is consistent with recent assessments indicating that informal storage and open dumping of organic waste contribute significantly to unaccounted greenhouse gas emissions in low- and middle-income countries (UNEP, 2023).

Open dumping and disposal-oriented collection services dominate waste pathways in the study area, indicating a systemic failure to capture the latent energy value embedded in organic waste. Studies using field-based emission measurements have shown that unmanaged food waste disposal can release methane at rates comparable to poorly managed landfills, yet without any form of energy utilisation or emission control (Serrano *et al.*, 2022). The results therefore highlight not only an environmental burden but also a missed opportunity for renewable energy generation and climate mitigation.

4.3. Infrastructure Constraints and the Case for Decentralised Bioenergy Systems

The absence of accessible, approved disposal infrastructure in Okuokoko has direct implications for energy system design. Long travel distances to disposal points increase

the likelihood of indiscriminate dumping while simultaneously rendering centralised waste treatment facilities inefficient. From a systems optimisation perspective, decentralised bioenergy technologies are increasingly recognised as more appropriate in contexts where waste generation is spatially dispersed and formal infrastructure is limited (Liu *et al.*, 2021).

Recent modelling studies suggest that community-scale anaerobic digesters outperform centralised facilities in peri-urban settings when transport energy, emission leakage, and operational reliability are considered (Cudjoe *et al.*, 2023). The infrastructural realities observed in Okuokoko therefore align with emerging global recommendations advocating for decentralised organic waste-to-energy systems as both technically and environmentally preferable solutions in similar socio-spatial contexts.

4.4. Social Readiness and Behavioural Dimensions of Waste-to-Energy Adoption

The results reveal a notable disparity between general environmental awareness and specific knowledge related to food waste recycling and energy recovery. While participation in sanitation activities is high, awareness of food waste valorisation pathways remains limited. This divergence is well documented in environmental behaviour research, which consistently shows that general pro-environmental attitudes do not automatically translate into acceptance of new waste-to-energy technologies (Bouman *et al.*, 2021).

However, the high level of engagement in sanitation activities suggests a strong foundation for community-based interventions. Evidence from recent pilot projects indicates that when bioenergy systems are framed as solutions to immediate sanitation and public health challenges—rather than purely as energy technologies—community acceptance and sustained participation increase significantly (Kibler *et al.*, 2022). In this regard, the social context in Okuokoko appears conducive to the introduction of food-waste-to-energy

initiatives, provided that targeted education and participatory planning mechanisms are employed.

4.5 Environmental and Public Health Co-Benefits of Energy Recovery

The occurrence of waste-related health issues and persistent environmental nuisances such as odour and vermin underscore the broader implications of unmanaged food waste. Recent epidemiological studies have linked proximity to informal waste disposal sites with increased incidence of gastrointestinal and vector-borne diseases, particularly in densely populated communities (He *et al.*, 2021). The results from Okuokoko are therefore consistent with a growing body of evidence highlighting the public health costs of inadequate organic waste management.

Energy recovery through controlled anaerobic digestion offers a pathway to simultaneously address sanitation, health, and climate objectives. Beyond methane capture, digestate by-products have been shown to improve soil quality when appropriately treated, further extending the environmental benefits of food-waste-based bioenergy systems (Paolini *et al.*, 2022). These co-benefits are particularly relevant in resource-constrained settings, where integrated solutions are essential for sustainable development.

4.6 Implications for Environmental Monitoring and Policy Integration

From an environmental monitoring perspective, the findings underscore the need to move beyond waste quantity metrics toward integrated assessments that capture energy potential, emission pathways, and health outcomes. Recent advances in urban metabolism and circular economy monitoring frameworks emphasise the importance of embedding energy recovery indicators within municipal waste assessments (Bennich *et al.*, 2022).

For policy, the results suggest that food waste management strategies in Delta State—and similar regions—would benefit from explicit integration with renewable energy planning. Rather than treating waste management and energy production as separate sectors,

coordinated policies could enable the deployment of decentralised bioenergy systems that address multiple environmental challenges concurrently. Such integration aligns with emerging global policy directions advocating for waste-to-energy pathways as part of climate-resilient urban infrastructure (OECD, 2023).

5.0 Conclusion

This study demonstrates that household food waste in Okuokoko constitutes a consistent, biodegradable organic stream with clear potential for bioenergy recovery, while current management practices result in substantial environmental and energy losses. The dominance of daily food waste generation, coupled with preparation-related losses, confirms the availability and stability of feedstock suitable for decentralised anaerobic digestion. However, prevailing disposal pathways—characterised by open dumping, limited segregation, and disposal-oriented collection services—undermine opportunities for methane capture and renewable energy generation.

The findings further reveal that infrastructural deficiencies, particularly the absence of accessible and approved disposal facilities, constrain the effectiveness of centralised waste management approaches. In this context, decentralised food-waste-to-energy systems emerge as a technically appropriate and environmentally justified alternative, capable of reducing transport burdens, mitigating uncontrolled emissions, and improving local sanitation conditions. Importantly, the observed levels of environmental awareness and community participation suggest a social foundation upon which targeted waste-to-energy interventions could be successfully introduced.

From an environmental monitoring perspective, the study underscores the need to move beyond conventional waste quantity assessments toward integrated evaluations that explicitly account for energy potential, emission pathways, and public health implications. Such an approach would enable more informed decision-making and support

the alignment of waste management strategies with renewable energy and climate objectives.

Overall, the results indicate that integrating food waste management with decentralised bioenergy recovery could deliver multiple co-benefits in Okuokoko, including improved environmental quality, reduced health risks, and enhanced resource efficiency. Future research should focus on quantifying energy yields, emission reductions, and economic feasibility to support evidence-based implementation and policy integration at the municipal and state levels.

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