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Technical Analysis Of Solid Waste Management System In Akamkpa

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***Abstract*— In Akamkpa, solid waste management faces technical, operational and environmental issues, including outdated equipment, inadequate landfill management, and improper waste segregation. Inefficient practices lead to pollution and health hazards, which, if left unaddressed, may worsen with time. A technical assessment of Akamkpa's solid waste management system is necessary to identify and address deficiencies, promote sustainability and align the town's practices with best practices. Accordingly, in this work, technical analysis of solid waste management system in Akamkpa is presented. The study uses a mixed-methods approach to analyze the technical aspects of solid waste management system in Akamkpa, combining qualitative interviews, quantitative data collection, dumping sites inspection and field observations. A cross-sectional design was chosen to capture current solid waste management practices and infrastructure status in Akamkpa. The study area has average waste generation of 0.65 kg per person per day, waste collection frequency of 2 times per week, recycling rate of 12 % and landfill capacity utilization of 80 %. Also the solid waste composition consists of 55 % organic materials, 20 % plastic, 10 % paper and cardboard, 7 % metal and glasses. 3 % e-waste and 5 % other waste materials. Essentially, the study conducted technical analysis of solid waste management system in Akamkpa town, identifying critical gaps in waste collection, transport, landfill management and environmental impact. The findings reveal the need for urgent infrastructure upgrades and better waste segregation practices.**

Keywords* — *Solid Waste, Management System, Stakeholder Analysis, Stratified Sampling, Technical Analysis, Environmental Impact Assessment

1. Introduction

Background of the Study Solid waste management has evolved as a key environmental concern, particularly in developing areas where infrastructure may not keep pace with growing populations. Akamkpa Town is no exception. This region has seen a surge in waste generation due to increasing population and economic activities, particularly in mining, transportation, agriculture and small-scale industries. Solid waste refers to any discarded or abandoned material that is not liquid or gaseous [1,2,3]. Municipal solid waste is usually generated from human settlement, industrial activities and commercial activities of mankind [4,5,6]. It includes various types of waste generated from household, industrial, commercial, agricultural and construction activities [7,8] Solid waste management is a critical environmental and public health issue in Akamkpa, as in many other urban areas. The lack of effective waste management practices has led to environmental degradation, health risks, and economic losses [9,10].

This work aims to assess the current solid waste management strategy in Akamkpa and provide recommendations for improvement, with implications for sustainable development. The global population and increasing urbanization have increased the municipal solid waste generation. The cumulative effect of skyrocketing solid waste volume and the attendant growing complexity of such solid waste management in the modern economy have posed running challenges as well as serious risk to the ecosystems and also to human health [11,12]. This becomes a critical issue as a result of its management and inappropriate disposal. Thus, becoming a serious health concerned. This is usually seen particularly in the case of developing countries such as in semi-urban and rural areas. It tends to become a global issue that needs special attention. Solid waste management is an important aspect of sustainable development for any nation [13,14].

2. Methodology

2.1 Description of the Study Area

The study are is Akamkpa which is a local government area in Nigerian State of Cross River. Akamkpa Town has an approximate coordinate of 5.320725° N latitude and 8.347234° E longitude, as shown in the Google map visualization of the study area. It has its headquarters in the city of Akamkpa with a population of 151,125 as of 2006 census located at southern part of Nigeria. It is one of the eighteenths (18) local government area in Cross River State. It is rated as one among the richest local government in the country based on its blessed natural resources yet lacking an efficient solid waste management system. It has two constituencies I and II with 8-wards and a total landmass of 1,932 sq. mi (5,003km2). It hosts many communities such as Awi, Ayeabam, Nsan, Old Netim, Obung, Mbarakom, Oban, Ekureku, Iko Ekperem, Ekpri Ebutong, Umon Njangachan, Uyanga Model Town, Mfamosing and the rest of other communities.

Akamkpa as a town host many industries involved in mining, transportation, agriculture, construction and among others. It also hosts National Park and some notable institutions. Industrial activities become more with the potency of high generation of solid waste. Therefore, concern for effective solid waste management becomes a necessity.

Akamkpa Town comprises of eight (8) wards with villages. As a result of this, five (5) locations were chosen for the waste composition and segregation. These strategic locations are: Households, restaurants, institutional centers and market centers. Waste bins were provided for each of the location. The samples were received per day. The map of Akamkpa Local Government Area is shown in Figure 2.

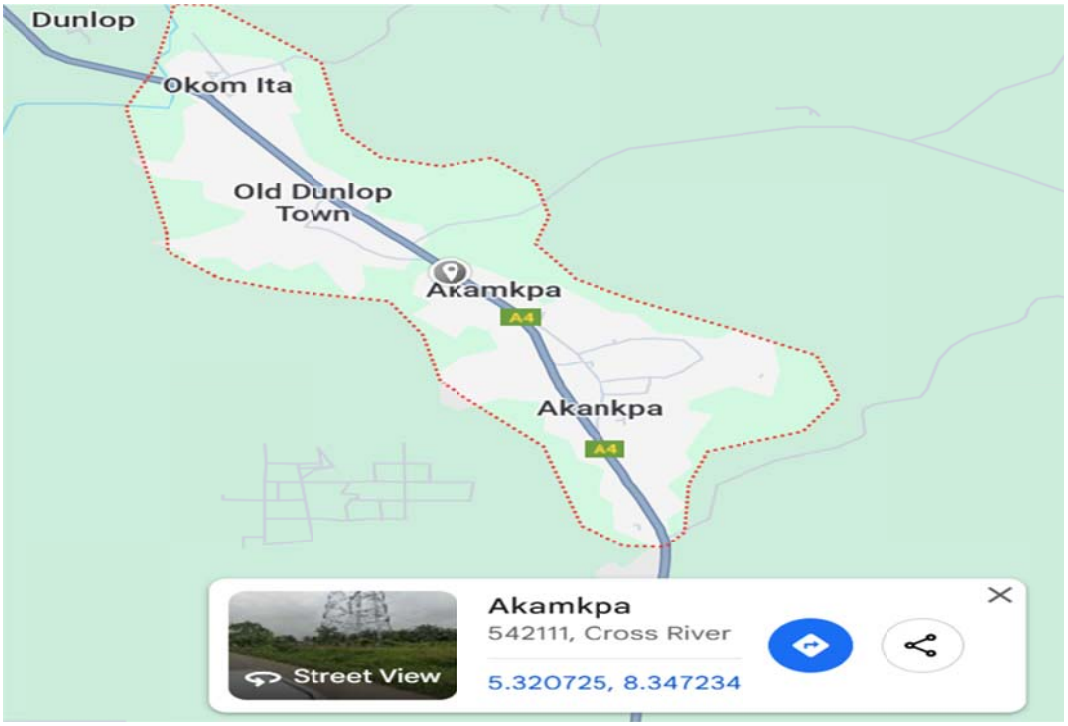

Figure 1 Google map visualization of the study area (Akamkpa local government area in Cross River State, Nigerian)

Figure 2: Map of Akampa Local Government Area

2.2 The Research Design

The study uses a mixed-methods approach to analyze the technical aspects of solid waste management system in Akamkpa, combining qualitative interviews, quantitative data collection, dumping sites inspection and field observations. A cross-sectional design was chosen to capture current solid waste management practices and infrastructure status in Akamkpa.

2.3 Data Collection Methods

i. **Surveys**: Structured surveys were distributed to residents, waste management staff and local authorities to gather data on waste generation rates, collection efficiency and infrastructure satisfaction. This is shown in Appendix IV.

ii. **Interviews**: Semi-structured interviews with solid-waste management personnel and town officials provided in-depth insights into technical and operational challenges. The Key Informant Interview (KII) Guide is shown in Appendix III

iii. **Field Observations**: Inspections of waste collection points, landfill sites and transportation systems allowed for firsthand assessment of infrastructure and equipment.

2.4 The Sampling Strategy and Data Analysis Techniques

A stratified sampling approach was used to select different neighborhoods, commercial areas and public spaces, ensuring a representative sample from various areas of Akamkpa. The following **data analysis techniques were used:**

i. **Quantitative Analysis**: Survey responses were statistically analyzed using Excel, with metrics such as waste generation rates and collection frequency.

ii. **Qualitative Analysis**: Interviews were analyzed thematically to identify common technical challenges and areas for improvement.

iii. **Global Information System (GIS) Mapping**: Waste collection routes and disposal sites were mapped using GIS software, providing spatial insights into collection coverage and areas of high waste generation.

2.5 Stakeholder Analysis for the Research

Stakeholder analysis is a critical component of the research and it was conducted to identify the individuals and groups that play vital roles in waste management in Akamkpa. Specifically, understanding their roles, interests, challenges, and potential contributions helps ensure a collaborative and sustainable approach to addressing the town's waste management issues. The summary of the key stakeholders and their engagement strategies are presented in Table 1. The engagement of the stakeholders listed in Table 1 ensures that the research provides thorough understanding of solid waste management in Akamkpa. The stakeholders' contributions and perspectives helped in the creation of sustainable solutions tailored to the town's unique challenges.

Table 1: Summary of Stakeholders and Engagement Strategies

Stakeholder	Role	Interest	Engagement Strategy
Government Agencies	Policy and oversight	Effective waste management	Policy reviews and discussions
Local Government Authorities	Operational implementation	Efficient service delivery	Collaborative meetings
Waste Management Contractors	Logistics and service delivery	Operational efficiency	Field visits and interviews
Community Members	Waste generation and disposal	Affordable and regular services	Surveys and community forums
Informal Waste Workers	Recycling and sorting	Livelihood support	One-on-one interviews
Educational Institutions	Research and education	Knowledge advancement	Research partnerships
NGOs	Advocacy and community engagement	Sustainable practices	Partnerships and joint projects
Business Owners	Waste generation	Reliable waste collection	Business-specific interviews

3. Results and discussion

3.1 Data for Survey, Interviews and Field Observation Schedule

The summary of the survey, interviews and field observation schedules (dates) with specific objectives are presented in Table 2. The dates well purposefully selected to allow sufficient time for analysis and adjustments to survey tools based on initial observations.

Table 2: Data for Survey, Interviews and Field Observation Schedule

Activity	Target Group	Date	Location	Objective
Survey Distribution	Households in selected areas	July - August, 2024	Residential areas	Collect data on household waste generation and disposal practices.
Interview	Waste Management Staff	August - September, 2024	Local Waste Offices	Gain insights on operational challenges and equipment conditions.
Interview	Community Leaders	September - October, 2024	Community Hall	Understand community perceptions and areas needing SWM improvement.
Field Observation	Waste Collection Sites	October, 2024	Major collection points	Document equipment status, waste segregation, and efficiency of operations.
Field Observation	Landfill Site	November, 2024	Akamkpa Landfill	Assess landfill engineering, pollution signs, and surrounding environment.
Survey Follow-up	Selected Businesses	December, 2024	Commercial areas	Gather data on commercial waste management and disposal practices.

3.2 Data for Sampling Strategy

The data for sampling strategy is presented in Table 3. The sampling strategy adopted a combination of stratified random sampling for households to cover socio-economic differences and purposive sampling for waste management staff and community leaders. The bar charts in Figure 3 shows the proportion of different sample group as contained in Table 3.

Table 3: Data for Sampling Strategy

Sample Group	Population Size	Sample Size	Sampling Method	Details
Households	2,500	300	Stratified Random	Stratified by neighborhoods (low, middle, and high-income areas) to ensure diversity.
Commercial Businesses	500	50	Random Sampling	Focused on waste-intensive sectors (restaurants, markets).
Waste Management Staff	50	15	Purposive Sampling	Includes supervisors, drivers and landfill staff for comprehensive insight.
Community Leaders	10	5	Purposive Sampling	Selected from key neighborhoods for broad community representation.

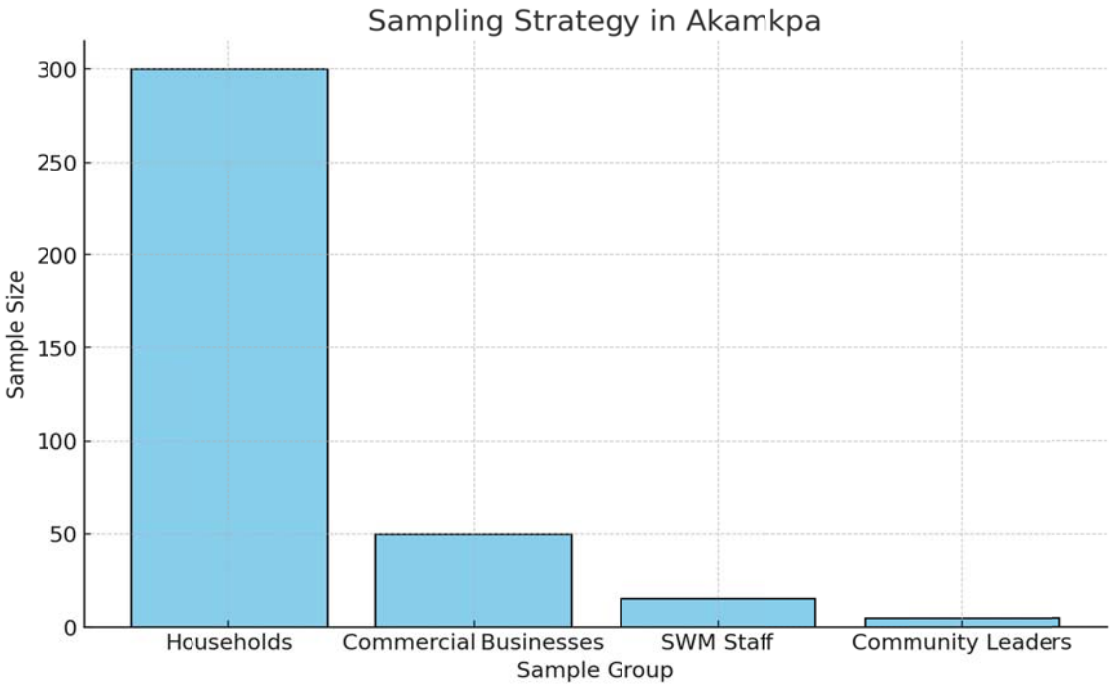

Figure 3: Sampling Strategy

3.3 Quantitative Analysis Data

The quantitative analysis of the data obtained from the research areas is presented in Table 4. The data points illustrate where technical improvements are most needed, such as increasing collection frequency and enhancing recycling capabilities. The histograms in Figure 4 shows the quantitative analysis metrics (patterns like waste generation rates) as contained in Table 4.

Table 4: Quantitative Analysis of Data

Metric	Result	Unit	Interpretation
Average Waste Generation	0.65	kg per person per day	Moderate generation rate; high in commercial zones.
Waste Collection Frequency	2	times per week	Below ideal frequency, leading to overflow in some areas.
Recycling Rate	12%	%	Low rate; highlights potential for enhanced recycling initiatives.
Landfill Capacity Utilization	80%	%	High; indicates landfill nearing capacity limits, risking overflow.
Community Satisfaction	56%	% satisfied	Low satisfaction due to irregular collection and inadequate bins.
Air Quality (Methane)	2.5	Ppm	Elevated levels near landfill; indicates inefficient decomposition.

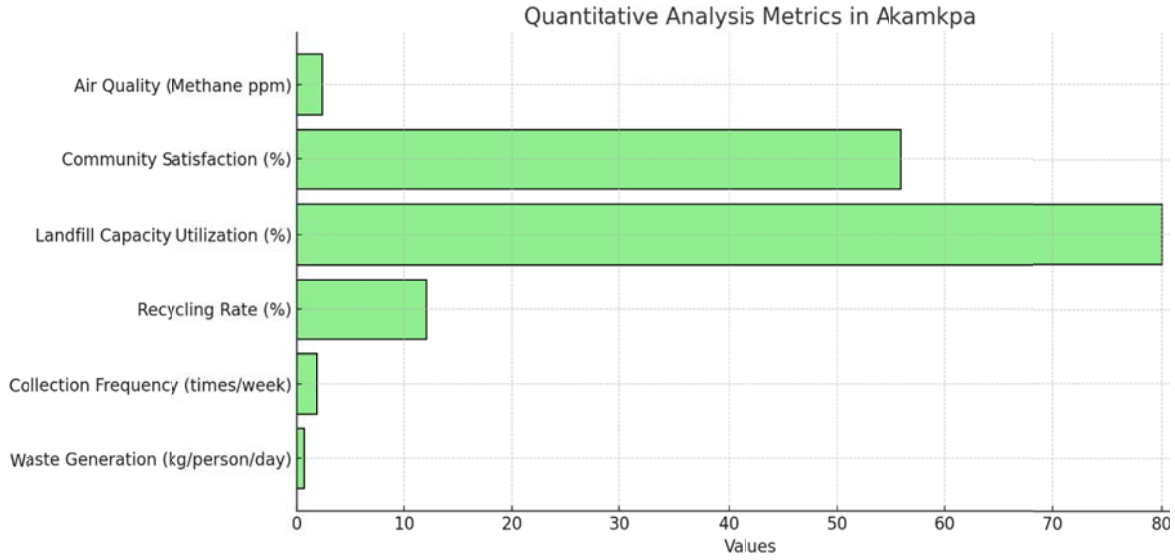

Figure 4 : Quantitative Analysis Metrics

3.4 Qualitative Analysis Data

The qualitative analysis of the data obtained from the field is presented in Table 5. The analysis gives insights which are essential in formulating recommendations that address both operational and community concerns.

Table 5: Qualitative Analysis of Data

Theme	Sample Responses	Interpretation
Operational Challenges	"No functional and structured solid waste department"; "We don't have equipment and staff."	Equipment and staffing shortages significantly impact service delivery.
Community Awareness	"Not many people separate their waste"; "We lack proper recycling centers."	Highlights the need for educational programs and better recycling facilities.
Environmental Concerns	"The landfill is too close to our homes"; "It smells bad, especially after rain."	Strong concerns around landfill location and management; risks to public health.
Infrastructure Needs	"We need better bins and more frequent pickups"; "More sorting stations would help with recycling."	Community desire for infrastructure improvements and more recycling options.
Perceptions of SWM Staff	"They work hard but are under-resourced"; "The staff needs better equipment."	Community sympathy for SWM staff but frustration with system inefficiencies.

3.5 Technical Analysis of Waste Collection and Transportation

Findings show that Akamkpa has no structured solid waste management system. Waste disposal systems are done locally without government regulations, burning of refuses are often seen in in some villages in Akamkpa. At times, outdated dump vehicles or trucks are often hired to evacuate waste occasionally, leading to breakdowns and irregular waste collection schedules. Many of these hired trucks lack modern compaction systems, resulting in reduced transport efficiency.

3.5.1 Infrastructure and Equipment Gaps

The study revealed that landfill sites lack proper engineering, such as lining and leachate collection systems, which increase the risk of soil and water contamination. Additionally, the absence of recycling facilities limits waste diversion efforts.

3.5.2 Environmental Impact

Environmental tests around landfill areas showed elevated pollutant levels in soil and water samples, indicating contamination from waste leachates. Air quality analysis revealed high methane levels around disposal sites, an indicator of inefficient waste decomposition practices.

3.5.3 Characterization of Solid Waste in Akamkpa

i. **Sources of Waste:** Solid waste in Akamkpa Town comes from diverse sources:

a. **Residential Areas**: Households generate the majority of waste, including food scraps, packaging materials, and discarded items. Example: "In many homes, leftover food, plastic wrappers, and used cooking oil containers are frequently disposed of without segregation."

b. **Commercial Areas**: Markets and shops contribute significant amounts of organic waste, plastics, and

cardboard. Example: "At the main Akamkpa market, heaps of vegetable peels, empty water sachets, and torn boxes pile up daily."

c. **Public Spaces**: Parks, streets, and bus stations contribute to littering, including single-use plastics and paper.

ii. **Composition of Solid Waste:** Based on field observations and the data obtained, the solid waste in Akamkpa can be divided into six categories which is captured in the pie charts of Figure 5; it shows the composition of solid waste generated in Akamkpa Town based on the six categories identified in the study

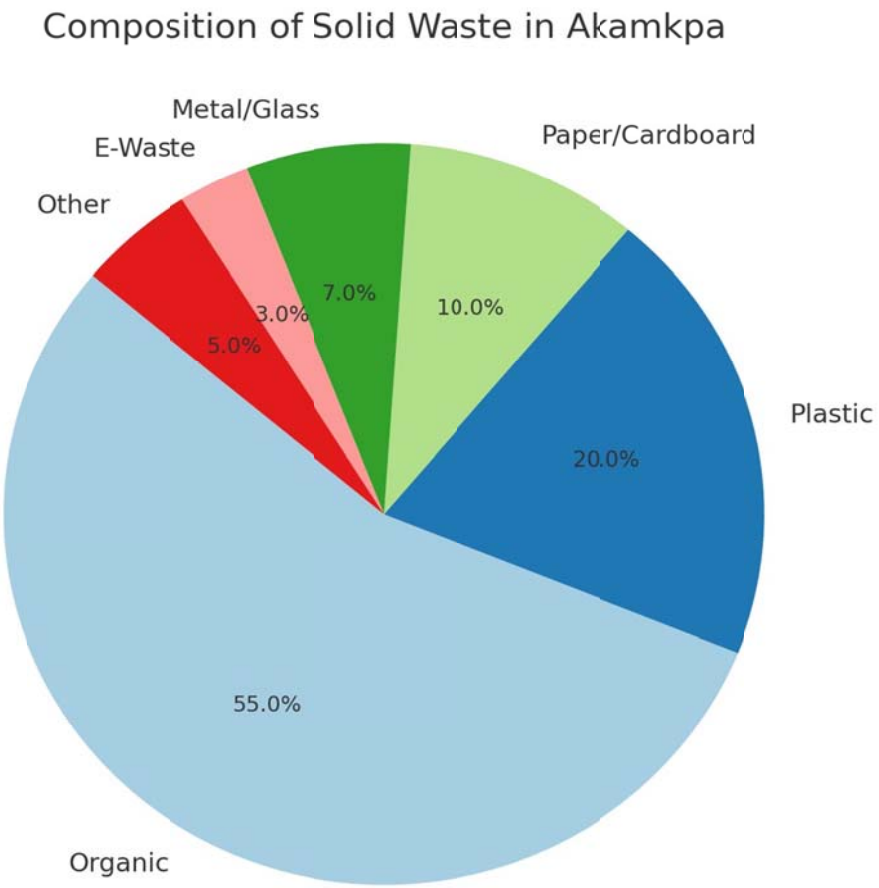

Figure 5: Composition of Solid Waste

iii. **Waste Generation Patterns**

a. **Volume**: The average household in Akamkpa generates approximately 0.6–0.8 kg of waste per person per day.

b. **Seasonal Variations**:

1. During festive periods, there is a noticeable spike in waste, especially plastics and organic materials. Example: "The December holidays had an influx of waste as people host events and markets get busier."
2. In the rainy season, improperly disposed waste often blocks drainage systems, exacerbating flooding.

The combination charts for waste generation characterization (volume trends and seasonal variations) is presented in Figure 6.

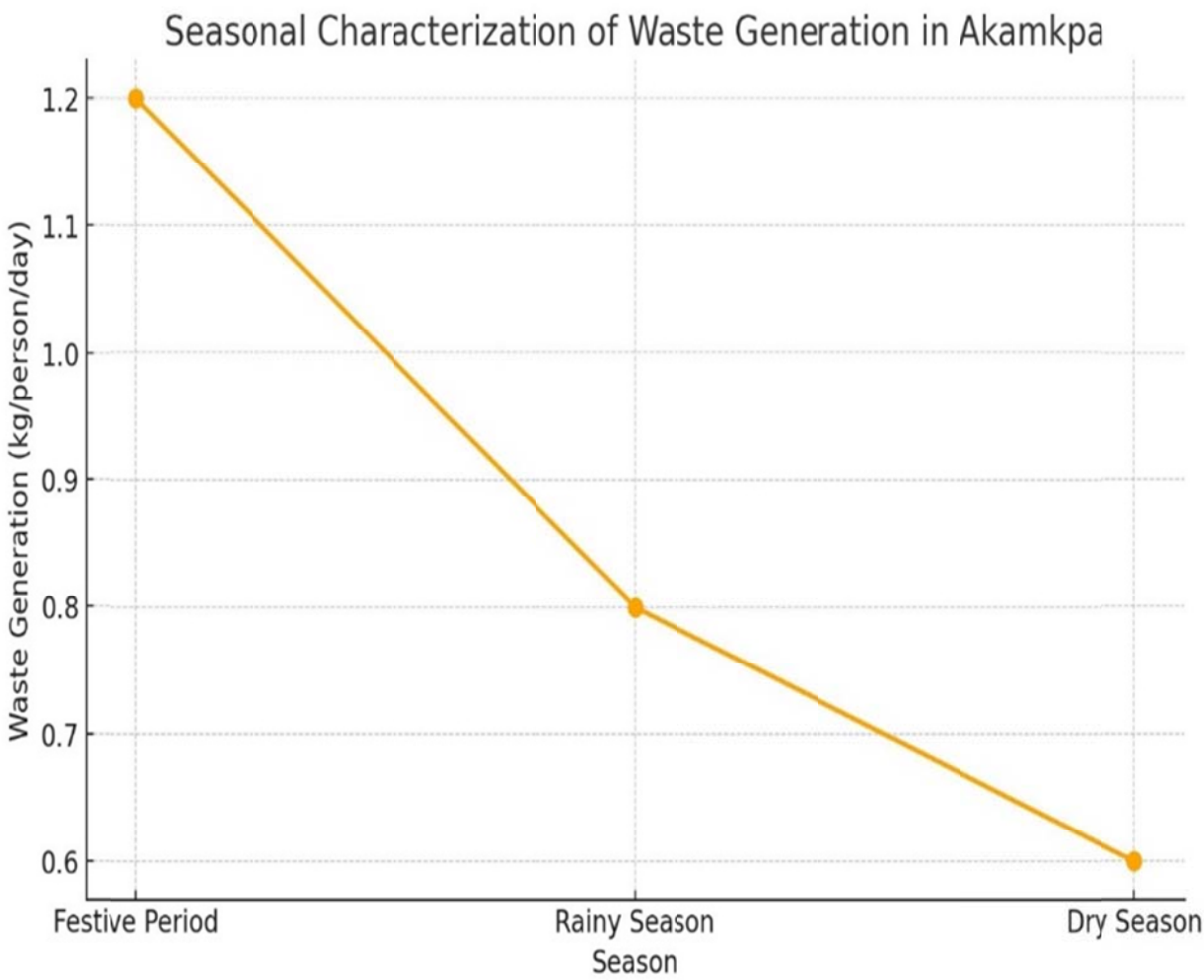

Figure 6: Waste Generation Characterization

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iv. **Challenges in Waste Management**

a. **Low Segregation**: Many residents mix organic and inorganic waste, making recycling and composting challenging. Example: "Most people don't think twice before tossing a banana peel and a plastic wrapper into the same bin."

b. **Unregulated Dumping**: Open dumping along roadsides and near water bodies is common. Example: "Behind some residential blocks, piles of waste can be seen attracting pests and emitting foul odors."

c. **Limited Recycling**: There are few recycling facilities, so plastics and metals often end up in landfills instead of being repurposed.

v. **Environmental and Health Impacts**

a. **Pollution**: Plastic and organic waste contribute to soil and water contamination. Example: "In some areas, rain washes waste into streams, polluting water sources used by locals."

b. **Health Risks**: Accumulated waste attracts pests and increases the risk of diseases like malaria, cholera, and respiratory issues.

v. **The Opportunities for Improvement**

a. **Composting Organic Waste**: Establishing community composting programs can turn food waste into valuable manure.

b. **Recycling Plastics**: Initiatives to collect and process plastics for reuse can help reduce environmental pollution.

c. **Public Awareness Campaigns**: Educating residents on waste segregation and recycling could drastically improve waste management efficiency.

3.6 Discussion of results

The findings indicate that Akamkpa's solid waste management system suffers from significant technical limitations, including inefficient equipment and inadequate landfill engineering. Findings also shows that Akamkpa has no structured solid waste management system. Waste disposal systems are done locally without government regulations, burning of refuses are often seen in in some

villages in Akamkpa. These issues pose environmental and public health risks.

In comparing these findings to previous research on solid waste management, a recurring theme emerges—many developing regions, including Akamkpa, face similar challenges related to inefficient waste management systems. Studies conducted in other parts of Nigeria and beyond have highlighted issues such as inadequate waste collection infrastructure, lack of government involvement, and heavy reliance on informal waste disposal methods, including open burning.

For instance, research conducted in urban centers like Lagos and Port Harcourt has shown that while waste management efforts exist, they are often hampered by poor funding, weak regulatory enforcement, and outdated disposal techniques. In contrast, Akamkpa appears to have even fewer formal structures in place, with no structured waste management system at all. This aligns with findings from rural areas in other parts of Nigeria, where waste disposal remains largely unregulated and relies on local, often environmentally harmful practices.

Similarly, studies from other developing countries, such as Ghana and India, have reported that the absence of engineered landfills and efficient waste collection systems contributes to pollution, health hazards, and environmental degradation. Akamkpa's case reinforces this pattern, as waste is often burned in villages, posing serious air quality concerns and potential health risks for residents.

Overall, while previous research acknowledges the challenges of waste management in both urban and rural settings, Akamkpa's situation appears more critical due to the complete lack of formal waste management infrastructure. This highlights an urgent need for government intervention, proper waste collection strategies, and sustainable disposal methods to mitigate the growing environmental and public health risks.

3.7 Expanded Findings for the Research

i. **Inadequate Waste Collection Coverage:** Only formal sectors (companies and institutions), some households and businesses in Akamkpa practices regular waste collection services. Many rural areas rely on self-disposal methods such as open burning or dumping in unauthorized locations. *Example*: A resident of a remote area shared, “We have no choice but to burn our waste because there is no provision for waste collection via trucks by government.”

ii. **Lack of Waste Segregation Practices:** Almost all surveyed households and businesses do not separate waste into recyclable and non-recyclable categories. This results in recyclable materials like plastics and metals ending up in landfills or dumpsites. *Example*: A market vendor said, “We throw everything into one bag because there are no separate bins provided.”

iii. **Poorly Maintained Infrastructure:** Many waste collection bins are either broken or insufficient in number. This leads to overflowing bins and delays in waste collection, especially during peak periods. *Observation*: “Some bins are so old and damaged that people prefer to dump waste on the ground,” reported a field worker.

iv. **Environmental Impact of Waste Mismanagement**

a. **Drainage Blockages**: Plastic waste clogs some drainage systems, contributing to flooding during the rainy season.

b. **Air Pollution**: Open burning of waste is a common practice in Akamkpa, releasing harmful gases that affect respiratory health.

c. **Water Contamination**: Leachate from improperly managed landfills pollutes nearby streams and rivers.

v. **Community Perceptions of solid-waste management:** While residents acknowledge the efforts of waste management authorities, they express dissatisfaction with the frequency of tax collection and the limited number of bins. *Example*: A shop owner lamented, “We pay for tax for waste services, but the bins are rarely supplied on time.”

vi. **Economic Opportunities in Waste Recycling:** There is untapped potential in recycling industries. Plastics, metals and organic waste can be processed into valuable products, but a lack of facilities and awareness limits these opportunities.

4. Conclusion

The research on the **Technical Analysis of Solid Waste Management System in Akamkpa Town** explored the current state of waste management, its challenges and opportunities for the much desired improvement. By combining field observations, community surveys, interviews, quantitative and qualitative analysis, a comprehensive picture of the waste management system in Akamkpa emerged. This study provides a technical analysis of solid waste management system in Akamkpa town, identifying critical gaps in waste collection, transport, landfill management and environmental impact. The findings reveal the need for urgent infrastructure upgrades and better waste segregation practices.

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