KAMPALA INTERNATIONAL UNIVERSITY

KIU
Journal of Science, Engineering and Technology

KJSET Research Article

Municipal solid waste composition in Jos Metropolis: Seasonal and Metropolis-wide characterisation

***Joseph Ajiya Japhet[1], Gyang Yakubu Pam[2], Talib Onimisi Ahmadu[2] and Zamani Donald Ishaya[2]**

[1] *Department of Mechanical Engineering, University of Jos, Plateau State, Nigeria.*
[2] *Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria.*
ajiyaj@unijos.edu.ng, gypam@abu.edu.ng, toahmadu@abu.edu.ng, zdishaya@abu.edu.ng
Corresponding Author: ajiyaj@unijos.edu.ng

Paper history:
Received 16 February 2026 Accepted in revised form 26 May 2026

Keywords
Municipal solid waste; Waste composition; Seasonal variation; Bulk density; Waste characterisation; Sustainable waste management

Abstract

Municipal solid waste (MSW) generation is increasing rapidly in developing countries, yet reliable city-scale composition data remain limited, constraining sustainable waste management planning. This study presents a detailed metropolis-wide and seasonal characterisation of MSW in Jos metropolis, Nigeria. The city, which is rapidly urbanizing, faces challenge of low waste collection efficiency and heavy dependance on open dumping. A stratified sampling approach was adopted, covering Jos North and Jos South Local Government Areas. waste samples were collected from four major dumpsites to capture spatial and socio-economic variability. Characterisation was carried out over ten months (April 2024–January 2025) to account for seasonal changes. Results revealed that food and putrescible waste accounted for 38.0% of total MSW, increasing to 44.3% with wood waste, confirming the dominance of biodegradable materials. Polythene and plastics accounted for 16.18% and 2.31%, respectively, indicating increasing packaging waste linked to urban transition. Notable seasonal variation was observed in waste properties, with bulk density decreasing from 310.25 kg/m³ in Season 1 to 222.92 kg/m³ in Season 3 (annual mean: 272.63 kg/m³). The findings highlight an organic-rich waste stream with distinct local characteristics. This study provides reliable baseline data to support integrated waste management strategies emphasising biological treatment, recycling, and improved collection systems in Jos Metropolis.

1.0 Introduction

Municipal solid waste (MSW) consists of unwanted materials discarded from daily human activities and environmental interactions (Ibikunle *et al.*, 2019). It includes waste from households, institutions, commercial and industrial premises, and public spaces, collected or managed by municipal authorities (Ahmed, 2012; Staley & Barlaz, 2009; Buah *et al.*, 2007; Tchobanoglous & Kreith, 2002; U.S. EPA, 2014; UN-HABITAT, 2010). Globally, MSW generation is escalating, projected to increase from 2.01 billion tonnes in 2016 to 3.40 billion tonnes by 2050, driven by urbanization and modern lifestyles (Kaza *et al.*, 2018; Islam, 2016). In developing countries, inadequate infrastructure, low collection coverage (20–80%), and reliance on open dumping and landfilling exacerbate environmental risks, including methane emissions with a global warming potential 27–30 times that of CO_2 over 100 years (Adedara *et al.*, 2023; Silpa & Perinaz, 2018; US EPA, 2023). Reliable data on waste generation rates and composition remain critical for effective municipal solid waste management (MSWM), yet such data are often scarce in Sub-Saharan Africa (Adedara *et al.*, 2023; Moya *et al.*, 2017).

Nigeria exemplifies these challenges, generating over 32 million tonnes of MSW annually with only 20–30% collected, largely due to rapid population growth, limited infrastructure, and widespread open dumping (Ibikunle *et al.*, 2019; Ukwaba *et al.*, 2018; Ogechukwu & Emeka, 2020). In Jos Metropolis, Plateau State – one of Nigeria's rapidly urbanizing centers – the situation is particularly acute. From a population of approximately 10,000 in 1930, Jos grew to over 1.3 million by 2006 and is projected to reach about 2.7 million by 2025, driven by historical tin mining, temperate climate, economic opportunities, and influxes of internally displaced persons and refugees (Bingel, 1978; Dung-Gwom, 2008; Yakubu, 2017). This rapid expansion has led to sharply increased MSW generation, widespread indiscriminate disposal along streets, roadsides, drainages, bridges, and open spaces, and severe environmental and health impacts, including air, water, and land pollution as well as elevated malaria risk from stagnant water in polythene bags (Eche *et al.*, 2015; Peter *et al.*, 2014; Gyang & Ashano, 2010; Yakubu, 2017). The Plateau Environmental Protection and Sanitation Agency (PEPSA) faces chronic constraints such as insufficient funds, inadequate vehicles and containers, limited staffing, and weak enforcement, resulting in collection of only about 50% of waste and reliance on open dumpsites without sanitary landfills (Yakubu, 2017; Efe, 2013; Peter, 2016).

Previous studies in Jos have examined institutional performance (Eche *et al.*, 2015; Binbol *et al.*, 2013; Da'am *et al.*, 2020), challenges in low-income areas (Yakubu, 2017), e-waste awareness (Miner *et al.*, 2020), and general waste generation patterns (Ali *et al.*, 2016; Peter *et al.*, 2014). Recent work in low-income households reported waste composition as approximately 65.2% biodegradable, 13.2% recyclable, and 21.6% residual, with generation rates of 0.55–0.58 kg per capita per day (Yakubu *et al.*, 2023; PEPSA, 2013). However, these studies are limited by narrow socioeconomic coverage, reliance on single source, restricted seasonal data, and lack of full metropolis-wide integration. Consequently, there remains a significant gap in comprehensive, representative characterization of MSW composition across the entire Jos metropolis, encompassing diverse socioeconomic groups, multiple sources seasonal variations and city-wide patterns.

Thus, to address this critical gap, the primary objective of this study is to characterise the composition of municipal solid waste across Jos Metropolis through a comprehensive, city-wide approach. By providing representative data on waste composition, this study seeks to support the development of effective and sustainable MSW management strategies in Jos – including waste-to-energy recovery, recycling, and integrated waste management systems. Thus, it is essential for mitigating environmental and health impacts while supporting economic development in Jos (Adeleke *et al.*, 2021; Scarlat *et al.*, 2015; Makarichi *et al.*, 2019; Omari *et al.*, 2014b).

2.0 Materials and Methods

2.1 Study area:

The study was conducted in Jos, the capital city of Plateau State, Nigeria. The city is situated between latitudes 9°55′N and longitudes 8°53′E, at an elevation of approximately 1,220 m above sea level. It encompasses Jos North and Jos South Local Government Areas (LGAs). According to the 2006 National Census, Jos North had a population of 429,300, and Jos South had 306,716 (National Population Commission, 2006). Jos experiences a temperate-like climate due to its high elevation, with a mean annual temperature of about 22°C, ranging from 19°C in December to 25°C in April. The annual average rainfall is approximately 1,250–1,400 mm, peaking between July and August (various sources, e.g., climate data for Jos Plateau). The city is multicultural, with significant populations of Yoruba, Igbo, Hausa, and other Nigerian ethnic groups, alongside immigrant communities from within Nigeria and abroad. As in many Nigerian cities and other developing countries, MSW management remains underdeveloped. The Plateau Environmental Protection and Sanitation Agency (PEPSA) is responsible for waste collection, but limited resources result in only about 50% of generated waste being collected (Efe, 2013). Open dumping is the predominant disposal method, owing to the absence of sanitary landfills (Da'am *et al.*, 2020). Two main practices exist: PEPSA-managed open dumpsites and informal community dumping in backyards or open spaces (Yakubu, 2017).

2.2 Sampling Methodology

A stratified sampling design was used to characterise MSW in Jos metropolis. The covered Jos North and Jos South Local Government Areas (LGAs). Stratification based on socioeconomic and geographic characteristics improves representativeness in MSW studies (Tchobanoglous *et al*., 1993; Guerrero *et al*., 2013). Two main strata were defined:

i. Jos North LGA: Predominantly urban with mixed-to-higher socioeconomic status.
ii. Jos South LGA: Urban–peri-urban areas with generally lower-to-middle socioeconomic status.

Four major dumpsites were purposefully selected as sampling points. These were Bauchi Road and Rukuba Road in Jos North and Building Materials and Rayfield in Jos South. Selection key disposal sites is a standard and accepted approach in waste characterisation studies in developing countries (Hoornweg & Bhada-Tata, 2012).

2.3 Sample Collection and Preparation

MSW samples were collected directly from incoming truckloads during unloading at the selected dumpsites. Sampling was conducted over a 10-month period from April 2024 to January 2025. This was so done to capture seasonal variation in waste composition across the three major climatic periods in the region (Table 1). Seasonal variation in MSW composition have been well-documented in literature (Daura, 2016).

Table 1: Seasons in a year

Description	Season 1	Season 2	Season 3
Months	March – May	June – October	November – February
Type of season	Hot/dry	Rainy/wet	Harmattan/dry

At each dumpsite, trucks were selected using simple random sampling. This was achieved by sampling different incoming vehicles at varying times and days across the entire study period. The procedure minimised temporal bias and ensured the collection of representative waste sample. A 240 litres sub-sample was collected from each selected truckload. This was achieved by collecting two separate 120-litre portions. The procedure followed the volume-based sampling method recommended by the European Commission Solid Waste Analysis Tool (EC SWA-Tool, 2004). Samples were collected from different sections of the waste stream during unloading to improve representativeness.

Three samples were collected monthly across the four selected dumpsites to ensure representative spatial coverage of both Jos North and Jos South LGAs. The collection intervals were between 7–10 days, giving approximately 30 samples during the study period. This sampling frequency minimised temporal bias and achieves the minimum samples for reliable MSW characterization studies (EC SWA-Tool, 2004; Ibikunle *et al*., 2019). Each sample was labelled according to date. The sampling approach was designed to obtain an overall representation of MSW composition across the study area rather than site-specific waste characteristics.

2.4 Waste Sorting and Characterization

MSW sorting and characterisation conducted following the EC SWA-Tool, (2004). This is a methodological framework for standardised waste composition analysis. The protocol has been applied in previous MSW characterisation studies for generating consistent and comparable datasets (e.g., Ibikunle *et al*., 2019).

Collected 240-litre waste samples were manually sorted using custom-built screening unit measuring 1.2 m × 0.9 m × 0.15 m with a mesh size 10 mm × 10 mm. The screening design was adapted from the mixed solid waste screening approach recommended by the World Health Organization and previously applied in related studies (Issam *et al.*, 2010; Ibikunle *et al*., 2019). Sorting was carried out on-site immediately after sample collection using appropriate personnel protective equipment (PPE) to minimise contamination and ensure operational safety.

Waste fractions were classified into nine categories: Food waste, wood, papers/cardboard, textiles, polythene, plastics, metals, glass and silt/others (including sand, stones, ash, etc.). Polythene was classified separately from rigid plastic materials due to differences in physical characteristics, disposal patterns and recycling potential. Each fraction was weighed separately using a calibrated digital weighing balance. The percentage composition by mass was determined relative to the total sample weight using Equation 1. To improve data reliability, measurements were recorded immediately after sorting to minimise moisture loss and handling errors.

$$\%\,Weight = \frac{Weight\ of\ Constituent}{Total\ Weight\ of\ Sample} \times 100 \qquad (1)$$

Monthly composition values were obtained by aggregating individual sample results. The overall waste composition for the study period was derived from the cumulative 10-month dataset (Table 1).

2.5 Bulk Density Determination

Bulk density of MSW was determined using a gravimetric–volumetric method adapted for field conditions. This parameter is esential for converting measured waste volumes to mass, estimating landfill capacity, and designing waste collection and transportation systems and conducting material flow analyses (Tchobanoglous *et al*., 1993; EPA, 1996).

A rigid container with a known internal volume of 200 – 300 litres (0.2 – 0.3 m³) was used for the measurements. This volume range is recommended for representative assessment of heterogeneous municipal waste (ASTM, 2019). The procedure followed standardised field protocols applied in developing-country MSW characterisation studies (Ibikunle *et al*., 2019).

The empty container was first weighed to obtain the tare weight. Representative waste sub-samples were placed loosely into the container until it was level-full. The filled container was then dropped three times from a height of approximately 10 cm onto a firm surface to simulate natural settling and minimise excessive void spaces (EPA, 1996). Any resulting headspace was refilled with additional waste to restore a level surface. The gross weight of the filled container was recorded and the net mass of waste (M) was calculated by subtracting the tare weight.

Bulk density (ρ) was calculated using the formular:

$$\rho = \frac{M}{V} \qquad (2)$$

where M represents the net mass of waste (kg) and V is the internal volume of the container (m³). The resulting bulk density was expressed in kg/m³. To improve accuracy and reduce the influence of variability in waste composition and moisture content, replicate measurements were averaged for each sampling period (ASTM, 2019; Tchobanoglous *et al*., 1993).

This method provides a practical and reliable compromise between loose-fill and compacted bulk density, consistent with field-based MSW studies in similar context (Ibikunle *et al.*, 2019). The resulting bulk density data were integrated with waste composition analyses to support accurate estimation of waste quantities and planning of sustainable waste management systems in Jos Metropolis.

2.6 Statistical Analysis

Statistical analysis was conducted to evaluate seasonal variation in MSW composition and bulk density in Jos Metropolis. Descriptive statistics including mean and standard deviation were calculated for all waste categories. One-way analysis of variance (ANOVA) was used to determine whether significant differences existed among seasonal waste composition and bulk density values at a 95% confidence level ($p < 0.05$). In addition, comparative descriptive assessment was used to examine variability among the selected dumpsites based on observed waste composition patterns. Statistical interpretation was performed using monthly composition data aggregated according to the three identified seasons.

3.0 Results and Discussions

The physical composition and bulk density of the MSW in Jos Metropolis were determined through detailed sampling campaign conducted across hot, rainy and harmattan seasons. Waste was collected from 4 locations distributed throughout the metropolis, yielding a total analysed mass of 1819.66 kg. The results are organised as follows: first, the aggregate metropolis-wide waste composition; second, the overall MSW composition and statistical summary, thirdly a comparison of percentage composition between hot, rainy and harmattan seasons to highlight temporal variation and lastly, the measured bulk density of the MSW.

3.1 Results

Table 2: Monthly mass composition of MSW in Jos metropolis (kg) (April, 2024 – January, 2025)

Waste types	APR.	MAY	JUN.	JUL.	AUG	SEP.	OCT.	NOV.	DEC.	JAN.	Total Mass (kg)
Food & Organics	60.42	85.65	96.75	55.39	73.2	69.15	75.63	56.95	64.73	53.54	691.41
Wood	1.91	2.70	5.50	20.23	15.45	24.50	21.73	14.42	2.21	5.56	114.21
Paper/ Cardboard	7.29	8.18	9.30	16.24	7.65	10.65	7.04	5.50	8.66	5.47	85.98
Textile	28.27	25.80	13.45	10.73	10.20	23.45	11.49	10.45	11.02	7.69	152.55
Polythene	22.68	42.00	32.30	48.36	24.08	32.85	29.84	20.15	23.27	18.94	294.47
Plastic	5.75	3.75	6.35	5.22	3.90	2.75	3.35	3.82	4.14	3.05	42.08
Metal	1.48	0.35	0.90	0.22	0.68	0.25	0.42	0.62	0.95	0.94	6.81
Glass	1.22	1.60	3.65	2.47	1.80	1.75	1.96	1.02	1.50	2.67	19.64
Silt/Others	33.57	46.05	26.10	59.52	34.05	35.65	45.50	41.52	36.64	53.91	412.51
Monthly Total (kg)	**162.59**	**216.08**	**194.30**	**218.37**	**171.00**	**201.00**	**196.96**	**154.44**	**153.14**	**151.78**	**1819.66**

Table 3: Overall MSW composition and statistical summary for Jos metropolis (April, 2024 – January, 2025)

Waste types	Total Mass (kg)	Composition (%)	Mean ± Standard deviation (kg)
Food & Organics	691.41	38.00	69.14 ± 14.02
Wood	114.21	6.28	11.42 ± 8.82
Paper/ Cardboard	85.98	4.73	8.60 ± 3.12
Textile	152.55	8.38	15.26 ± 7.52
Polythene	294.47	16.18	29.45 ± 9.69
Plastic	42.08	2.31	4.21 ± 1.18
Metal	6.81	0.37	0.68 ± 0.39
Glass	19.64	1.08	1.96 ± 0.78
Silt/Others	412.51	22.67	41.25 ± 10.16
Total	**1819.66**	**100.00**	**-**

Table 4: Seasonal average percentage composition of MSW in Jos Metropolis

Waste types	Season 1	Season 2	Season 3
Food & Organics	38.57	37.70	38.14
Wood	1.22	8.90	4.83
Paper/ Cardboard	4.09	5.18	4.27
Textile	14.28	7.06	6.35
Polythene	17.08	17.06	13.58
Plastic	2.51	2.20	2.40
Metal	0.48	0.25	0.55
Glass	0.74	1.18	1.13
Silt/Others	21.03	20.46	28.75
Total	100.00	100.00	100.00

Table 5: Average seasonal bulk density of MSW in Jos Metropolis

Season	Bulk density of waste (kg/m^3)
Season 1	310.25
Season 2	284.73
Season 3	222.92
Annual mean	**272.63**

3.2 Discussions

3.2.1 Municipal solid waste composition in Jos Metropolis

Figure 1 demonstrates consistent dominance of biodegradable waste throughout the sampling period, with food and organic waste contributing between approximately 35% and 50% of total monthly waste composition. Similar trend has been reported in Nigerian cities such as Abuja, as well as other developing urban centres where biodegradables exceed 40–50% of MSW (Imam *et al*., 2008; Kaza *et al*., 2018). Polythene remained the second-largest waste fraction, ranging from about 13% to 22%, indicating increasing dependence on packaged materials associated with urbanization. Silt/others (~21 – 28%) also contributed substantially, reflecting contamination from street sweeping, dust, and mixed disposal practices. This is consistent with emerging waste trends across low- and middle-income countries (Kaza *et al.*, 2018)

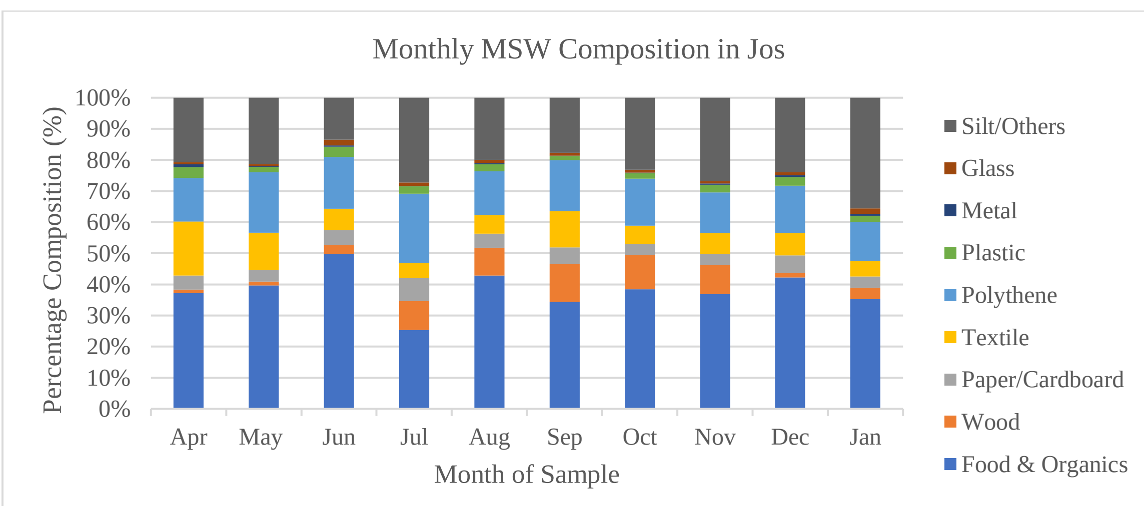

Figure 1: Monthly MSW composition in Jos expressed as percentage contribution of individual waste fractions using a 100% stacked column chart

3.2.2 Classification of wood within the organic fraction

Wood waste was presented separately due to its lower moisture content and slower biodegradation compared with food waste, which influences treatment options such as composting, anaerobic digestion, or thermal recovery (Guerrero *et al.*, 2013). However, when combined with food organics, the biodegradable fraction better reflects overall biological treatment potential. This dual interpretation strengthens planning relevance while preserving operational classification consistency.

3.2.3 Seasonal variation and bulk density

Seasonal comparison revealed that biodegradable fractions remained relatively stable across all seasons (Figure 2). However, wood waste increased substantially during the rainy season (~ 9%), likely due to increased vegetation and market biomass disposal. The dry season exhibited elevated silt/others fractions (~ 29%), suggesting increased dust contamination and reduced moisture content. This is a common feature in developing urban centres (Guerrero *et al.*, 2013).

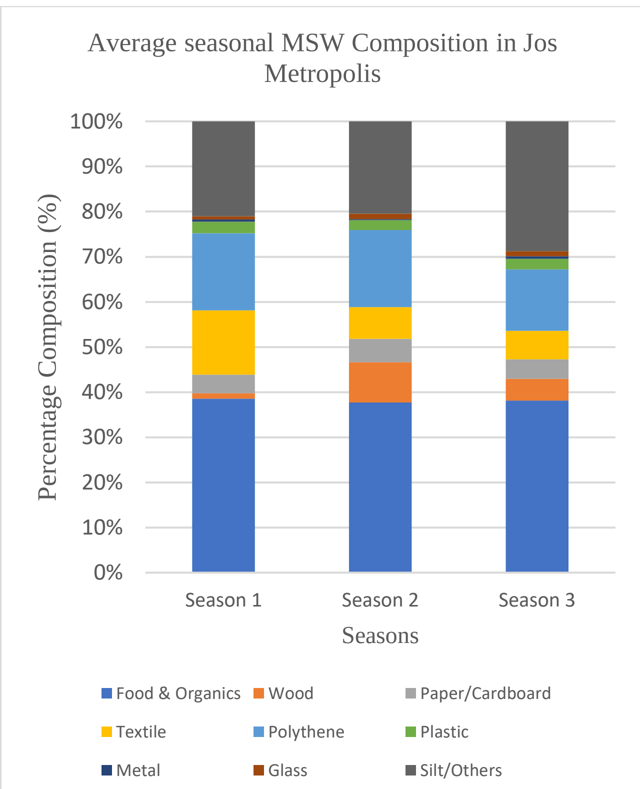

Figure 2: Average seasonal MSW composition in Jos expressed as percentage contribution of individual waste fractions using a 100% stacked column chart

Figure 3 shows a progressive decline in average bulk density from 310.25 kg/m³ in Season 1 to 222.92 kg/m³ in Season 3, representing an overall reduction of approximately 28%. This trend reflects seasonal moisture variation and changes in waste compactness, which directly influence transportation efficiency and landfill space requirements. Similar density variability has been documented in tropical developing cities (Imam *et al.*, 2008).

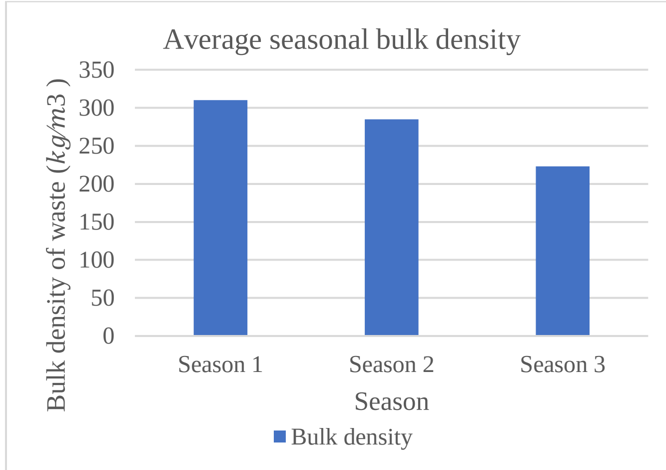

Figure 3: Average seasonal bulk density of MSW in Jos Metropolis

Descriptive statistical analysis and one-way ANOVA indicated that seasonal variation influenced the distribution of selected waste fractions and bulk density across the study period. Variability was more pronounced for wood waste, silt/others, and bulk density. This reflects climate influence on vegetation waste generation, moisture content, and environmental contamination during collection. However, biodegradable waste remained consistently dominant across all seasons, indicating relative stability in the overall waste stream composition of Jos Metropolis.

3.2.4 Why Jos differs from other Nigerian cities

Although organic dominance aligns with national trends, Jos differs from some Nigerian cities such as Lagos, Makurdi and Kano due to climatic and socioeconomic factors. Its cooler plateau environment, mixed urban–peri-urban structure, and lower industrial intensity likely reduce packaging waste while increasing biomass and inert fractions. Lower metal and glass proportions further suggest active informal recycling prior to disposal, consistent with observations in other developing-country systems (Wilson *et al.*, 2006).

To further contextualise the distinct waste characteristics observed in Jos, a comparative analysis was conducted using published waste composition data from selected Nigerian and other urban centres in developing regions (Table 5). This comparison is intended to position Jos within broader urban waste trends rather than to present additional primary data. As shown in Figure 4, Jos exhibits an organic-dominated waste profile similar to many developing cities, while maintaining relatively higher inert fractions compared with several Nigerian urban centres. These differences likely reflect local climatic conditions, mixed urban–peri-urban settlement patterns, and collection practices.

Table 5: Comparison of MSW composition in Jos Metropolis and selected Nigerian and urban centres in developing regions

Location	Organic fraction (%)	Plastics (%)	Inert/Silt (%)	Key observation	Reference
Jos Metropolis	44.3	18.5 (polythene + plastic)	22.7	Organic-dominated with high seasonal variation	Present study
Lagos, Nigeria	56	4	19	High organic content; strong informal recycling	Ogwueleka (2009)
Makurdi, Nigeria	52	8.2	14	Organic-rich waste typical of urban Nigeria	Ogwueleka (2009)
Kano, Nigeria	43	4	22	High inert fraction due to handling practices, strong informal recycling	Ogwueleka (2009)
Sub-Saharan African Average	43	8.6	30	High inert content	Kaza *et al.* (2018)
South Asia Average	57	8	15	High organic content	Kaza *et al.* (2018)

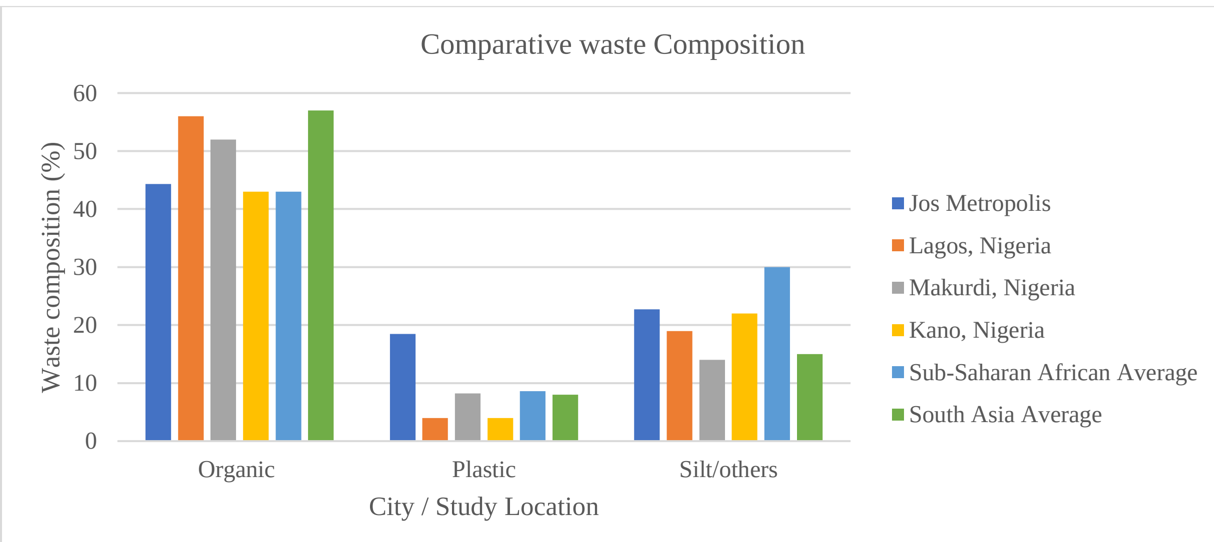

Figure 4: Comparison of MSW composition in Jos Metropolis and selected Nigerian and urban centres in developing regions

3.2.5 Comparison with other cities

The biodegradable fraction observed in Jos (44.3%) was lower than values reported for Lagos (56%) and Makurdi (52%), but comparable to Kano (43%). Conversely, the inert fraction in Jos (22.7%) exceeded that of Makurdi (14%) and Lagos (19%), suggesting stronger environmental contamination and mixed collection practices.

This comparison indicates that Jos represents an intermediate stage of urban waste transition, characterised by organic dominance alongside rising recyclable materials (18.5%) (Kaza *et al*., 2018).

3.2.6 Implications for waste-to-energy and integrated management

The high biodegradable fraction suggests strong suitability for composting and anaerobic digestion systems. The relatively high inert content may reduce thermal conversion efficiency and increase landfill demand. Similarly, seasonal reduction in bulk density has implications for transportation efficiency, storage capacity, and compaction requirements within waste management systems. These findings support integrated management approaches before final disposal (Kaza *et al*., 2018; Guerrero *et al.*, 2013).

3.2.7 Summary

MSW in Jos is characterised by a biodegradable-dominated composition, noticeable seasonal variability, and increasing plastic fractions. Compared with some Nigerian cities, local climatic and socioeconomic conditions produce a distinct waste profile, emphasizing the need for location-specific waste management strategies that integrate recycling, biological treatment, and controlled disposal.

4.0 Conclusion

Municipal solid waste in Jos Metropolis was predominantly biodegradable, with food and organic waste accounting for approximately 38% of the total waste stream. Polythene and inert materials constituted significant fractions. Seasonal variation influenced waste composition and bulk density, with bulk density declining from 310.25 kg/m³ during the hot/dry season to 222.92 kg/m³ during the harmattan period. This reflects the influence of climatic conditions on waste characteristics and handling requirements.

The high biodegradable content indicates strong potential for composting and other biological treatment technologies. The substantial inert fraction may reduce treatment efficiency and increase landfill burden. Overall, the study provides seasonally representative and metropolis-wide baseline data for sustainable waste management planning in Jos Metropolis. This highlights the need for improved source segregation, recycling systems, and integrated waste management strategies. This may enhance resource recovery and environmental sustainability.

References

Adedara, M.L., Taiwo, R., & Bork, H.-R. (2023). Municipal Solid Waste Collection and Coverage rates in Sub-Saharan African Countries: A Comprehensive Systematic Review and Meta-Analysis. Waste 1 (2), 389–413. https://doi.org/10.3390/ waste1020024.

Adeleke, O., Akinlabi, S., Jen, T., & Dunmade, I. (2021). Evaluation and Prediction of Energy Content of Municipal Solid Waste: A review. IOP, 1107(1), 012097. 1-18.

Ahmed, Y.A. (2012). Potential Impacts of Climate Change on Waste Management in Ilorin Nigeria. Global J. Hum. Soc. Sci. *12*(6), 39–45.

Ali, A.Y., Vivan, E.L., Ombugadu, A., Wambai, M.W., Dahiru, M.K., Njila, H.L. & Mafuyai, M.J. (2016). Waste Generation, Collection and Management Pattern in Jos City of Plateau State, Nigeria. *Book of Proceedings of 2nd Annual Conference of FULafia*, 213 – 229.

ASTM International (2019). ASTM E1109-19: Standard Test Method for Determination of Bulk Density of Solid Waste. ASTM International, West Conshohocken, PA.

Binbol, N.L. Ogboji, F. & Lohor, A.A. (2013). An assessment of waste management activities of Plateau State Environmental Protection and Sanitation Agency (PEPSA). From the selected works of Confluence Journal of Environmental Studies (CJES), Kogi State University, Lokoja, Nigeria.

Bingel, A.M. (1978), Jos: Origin and Growth of the Town (1900-1972), Occ. Pub. No 1., Dept of Geography, University of Jos.

Buah, W. K., Cunliffe, A. M., & Williams, P. T. (2007). Characterization of Products from the Pyrolysis of Municipal Solid Waste. Process Safety & Environmental Protection, 85(5), 450-457. https://doi.org/10.1205/psep07024.

Da'am, E. H., Wungakah, S. J., Kanma, R. D. & Bikalsoem, D. K. (2020): Assessment of solid waste management practices in Jos metropolis of plateau state, Nigeria. *International Journal of Current Research*, *12*(06), 12085-12089.

Daura, L.A. (2016). Electricity generation potential of municipal solid waste in kano metropolis. J. Sci. Eng. Res. 3 (4), 157–161.

Dung-Gwom, J. Y. (2008). The Nature of Peri-Urban Developments in Jos, Nigeria. Paper Presented at the XXXVI World Congress on Housing Science, National Housing Programme- New Vision, Kolkata, India, November, 3-7.

Eche, O.F., Yakubu, A.A., Lekwot, V.E., Kwesaba, D.A., Sohotden, & Daniel, C. (2015). An Assessment of Plateau Environmental Protection and Sanitation Agency (Pepsa) As a Waste Management Institution in Jos City, Nigeria. *International Journal of Scientific & Technology Research 4*(02), 2277-8616.

Efe, S.I. (2013). Waste Disposal Problems and Management in Ughelli, Nigeria. Journal of Environmental Protection. 4, 4-11.

EPA (1996). Municipal Waste Characterisation Procedures. Environmental Protection Agency, Ardcavan, Wexford, Ireland.

European Commission Solid Waste Tool (EC SWA-Tool), (2004). Development of a Methodology Tool to Enhance the Precision and Comparability of Solid Waste Analysis Data. Available from: www.wastesolutions.org.

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. Waste Management, 33(1), 220–232.

Gyang, J.D. & Ashano E.C. (2010). The role of geosciences in sustainable development of an expanding urban region: A case of the Jos-Bukuru urban region, North Central Nigeria. The Pacific Journal of Science and Technology. 11 (2), 664

Hoornweg, D. & Bhada-Tata, P. (2012). *What a waste: a global review of solid waste management.* World Bank Report.

Ibikunle, R.A., Titiladunayo, I.F., Akinnuli, B.O., Dahunsi, S.O. & Olayanju, T.M.A. (2019). Estimation of power generation from municipal solid wastes: A case Study of Ilorin metropolis, Nigeria. Energy Reports 5, 126–135.

Imam, A., Mohammed, B., Wilson, D. C., & Cheeseman, C. R. (2008). Solid waste management in Abuja, Nigeria. Waste Management, 28(2), 468–472.

Islam, K.M.N. (2016). Municipal solid waste to energy generation in Bangladesh: possible scenarios to generate renewable electricity in Dhaka and Chittagong city. Hindawi Publishing Corporation, Journal of Renewable Energy.

Issam, A.K.A., Maria, M.B., Salam, A.T., Saheed, H.Q. & Kassinos, D.B. (2010). Solid waste characterization, qualification, and management practices in developing countries, a case study: nubulus district-palestine. J. Env. Manage. 91, 1131– 1138.

Kaza, S., Yao, L., Bhada-Tata, P., & Woerden, F.V. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (Urban Development). The World Bank. http://hdl.handle.net/10986/30317.

Makarichi, L., Kan, R., Jutidamrongphan, W. & Techato, K. (2019). Suitability of municipal solid waste in African cities for thermochemical waste-to-energy conversion: the case of Harare Metropolitan City. Zimbabwe. Waste Management & Research 37 (1), 83–94. https://doi.org/10.1177/0734242X18804029.

Miner, K.J., Rampedi, I.T., Ifegbesan, A.P & Machete, F. (2020): Survey on Household Awareness and Willingness to Participate in E-Waste Management in Jos, Plateau State, Nigeria. *Sustainability*, *12*, 1047.

Moya, D., Aldas, ´ C., Jaramillo, D., J´ ativa, E. & Kaparaju, P. (2017). Waste-To-Energy Technologies: an opportunity of energy recovery from Municipal Solid Waste, using Quito Ecuador as case study. Energy Procedia 134, 327–336. https://doi.org/10.1016/j.egypro.2017.09.537.

Ogechukwu, N.A. & Emeka, C.H. (2020). A Review of Solid Waste Management Strategies in Nigeria. Journal of Environment and Earth Science 10 *(6)* 132 – 143

Ogwueleka, T.C. (2009). Municipal Solid Waste Characteristics and Management in Nigeria. Iran. J. Environ. Health. Sci. Eng. 6(3) 173-180

Omari, A., Said, M., Njau, K., John, G. & Mtul, P. (2014b). Energy recovery routes from municipal solid waste, A case study of Arusha-Tanzania. J. Energy Tech. Policy.

PEPSA, (2013). Report on Solid Waste in Jos, Nigeria.

Peter G., Hull A., Jowitt P. & Adeloye A. (2014). Municipal Solid Waste Management in Greater Jos, Nigeria. *The North American Conference on Sustainability, Energy and Environment 2014 Official Conference Proceedings.*

Peter, G. (2016). Planning for municipal solid waste management: the case of greater Jos, Nigeria. PhD thesis submitted to Heriot-Watt University, Energy, Geoscience, Infrastructure and Society. United Kingdom.

Scarlat, N., Motola, V., Dallemand, J. F., Monforti-Ferrario, F. & Linus, M. (2015). Evaluation of energy potential of Municipal Solid Waste from African urban areas. Renewable and Sustainable Energy Reviews *50*, 1269–1286

Silpa, K. & Perinaz, B.T. (2018). Decision maker's guides for solid waste management technologies.

Staley, B.F. & Barlaz, M.A., (2009). Composition of Municipal Solid Waste in the United States and Implications for Carbon Sequestration and methane Yield. Journal of Environmental Engineering 135 (10), 901–909. https://doi.org/10.1061/(ASCE) EE.1943-7870.0000032.

Tchobanoglous G. & Kreith, K. (2002). Handbook of Solid Waste Management. Second Edition. The McGraw-Hill Companies, Inc.

Tchobanoglous, G., Theisen, H., & Vigil, S. (1993). Integrated solid waste management, engineering principles and management issues. New York: McGraw-Hill Inc.

Ukwaba, S.I., Ikpe, A.E. & Orhorhoro, E.K. (2018). Adoption of a Landfill System in Nigeria and the Role of Municipal Solid Waste Segregation on its Performance. Nigerian Research Journal of Engineering and Environmental Sciences *3*(1), 280-286.

United Nations Human Settlements Programme (UN-HABITAT) (2010). Solid Waste Management in the World's Cities. Earthscan Ltd. Dunstan House, London and Washington, DC

US Environmental Protection Agency (US EPA) Website, (2023). Accessed 16-03-2024. https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

US Environmental Protection Agency (US EPA) (2014). Municipal Solid Waste Landfills. Economic Impact Analysis for the Proposed New Subpart to the New Source Performance Standards. U.S. Environmental Protection Agency Office of Air and Radiation Office of Air Quality Planning and Standards Research Triangle Park, NC 27711.

Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in developing countries. Habitat International 30, 797–808.

Yakubu, J. A. (2017): The Waste Management System in Low Income Areas of Jos, Nigeria: The Challenges and Waste Reduction Opportunities. *A thesis submitted in partial fulfilment of the requirements of the University of Brighton for the degree of Doctor of Philosophy.*

Yakubu, J. A., Woodard, R., & Aboagye-Nimo, E. (2023). Generation and composition of solid waste in low-income areas of Jos, Plateau State, Nigeria. World Journal of Advanced Research and Reviews, 18(02), 906–918.