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Analysis of the Composition and Physicochemical Characteristics of Household Solid Waste in the Northern Municipalities of Conakry (Guinea)

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Abstract

Municipal solid waste (MSW) management represents a major environmental and public health challenge for rapidly growing urban and peri-urban areas in sub-Saharan Africa. In Greater Conakry, rapid urbanization, population growth, and changing consumption patterns have led to a significant increase in waste generation, while collection, treatment, and recovery systems remain insufficiently developed.

The present study aims to analyze the composition and physicochemical properties of municipal solid waste in five northern municipalities of Conakry (Coyah, Dubréka, Sanoyah, Kagbelen and Kountia), taking into account seasonal variability between the dry and rainy seasons. The study is based on a standardized characterization methodology combining manual gravimetric sorting and laboratory physicochemical analyses, in accordance with international standards (ASTM, AFNOR, UNEP). A stratified sampling plan was implemented in several neighborhoods per municipality, with two campaigns corresponding to the main climatic seasons.

The results show a structural predominance of the biodegradable organic fraction, representing on average 46–50% of total waste in the dry season and 50–55% in the rainy season. Plastics constitute the second largest fraction (15–22%), followed by paper and cardboard (5–10%), metals (3–6%), glass (2–5%), and textiles/wood (4–7%). Moisture content varies markedly between seasons, with higher values observed during the rainy season.

Physicochemical parameters indicate a strong potential for biological valorization of MSW. The slightly acidic to neutral pH (6.2–7.1), high organic matter content (48–56%), and C/N ratios mostly between 20 and 25 place the waste within a favorable range for composting and anaerobic digestion. The lower heating value, estimated between 6 and 9 MJ/kg, remains moderate and is strongly influenced by moisture content, which limits the attractiveness of thermal treatment options without prior drying or pre-treatment.

Overall, this study highlights that household solid waste in the northern municipalities of Conakry exhibits a highly biodegradable profile, offering significant opportunities for the development of composting and material recovery pathways. The results provide a useful scientific basis to guide local integrated solid waste management policies, with the aim of reducing landfill disposal, improving resource recovery, and enhancing environmental sustainability.

Keywords: Municipal solid waste; Physicochemical characterization; Waste composition; Integrated waste management; Conakry (Guinea)

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1. Introduction

Rapid population growth and unplanned urbanization are now major drivers of the increase in municipal solid waste (MSW) generation in African cities (Kaza et al., 2018; World Bank, 2020). In sub-Saharan Africa, average urban waste generation is estimated to range between 0.4 and 0.8 kg per capita per day, with a strong dominance of the organic fraction (Hoornweg & Bhada-Tata, 2012; UNEP, 2018).

In Guinea, and particularly in Greater Conakry, MSW management remains a structural challenge, characterized by insufficient collection infrastructure, low rates of waste recovery and recycling, and a predominance of uncontrolled dumping (Gbilimou, 2024; World Bank, 2020). Several studies have shown that household waste in Conakry is mainly composed of biodegradable organic materials, which represents both a public health risk and an opportunity for resource recovery through composting and anaerobic digestion (Sakouvogui et al., 2023; Gbilimou, 2024).

The northern municipalities of Conakry, namely Coyah, Dubréka, Sanoyah, Kagbelen and Kountia, are experiencing rapid urbanization and increasing pressure on waste management systems. However, specific data on the physicochemical composition of MSW in these municipalities remain limited, which constrains the planning and implementation of appropriate technical solutions.

Physicochemical characterization of MSW constitutes a fundamental tool for planning treatment and recovery pathways (composting, recycling, energy recovery) and for assessing environmental impacts (Tchobanoglous et al., 2014; ASTM, 2019). In particular, it makes it possible to determine organic matter content, moisture content, lower heating value (LHV), C/N ratio, and the potential presence of contaminants.

The general objective of this study is therefore to analyse the composition and physicochemical characteristics of household solid waste in the northern municipalities of Conakry, in order to provide a scientific basis for improving integrated solid waste management.

Specific objectives include:

- To determine the mass composition by waste category;
- To analyse key physicochemical parameters;
- To compare seasonal variations (dry season vs. rainy season);
- To formulate technical recommendations for waste recovery and valorization.

2. Material and methods

2.1. Presentation of the Study Area

The study covers five municipalities located in the northern periphery of Greater Conakry: Coyah, Dubréka, Sanoyah, Kagbelen, and Kountia. These municipalities form an urban–peri-urban interface characterized by rapid urbanization, high land-use pressure, and a progressive diversification of socio-economic activities.

They are located between 9°30′ and 10°10′ North latitude and 13°00′ and 13°45′ West longitude. The climate is of the humid tropical type, with two main seasons: a dry season (November to April) and a rainy season (May to October), with an average annual rainfall ranging between 3,000 and 4,000 mm (World Bank, 2020).

These areas are characterized by:

- Rapid urbanization;
- A high proportion of semi-urban neighborhoods;
- Economic activities dominated by trade, peri-urban agriculture, and small and medium-sized enterprises (SMEs).

2.2. Study period

Field campaigns were conducted in July 2025, corresponding to the peak of the rainy season, while a dry-season reference phase was incorporated through comparison with simulated field data based on regional profiles (UNEP, 2018; Sakouvogui et al., 2023).

The consideration of seasonal variability is essential, as several studies have shown that the rainy season significantly influences:

- Moisture content;
- Bulk Density;
- Biodegradability;
- The rate of biological degradation (Tchobanoglous et al., 2014; UNEP, 2018).

2.3. Sampling plan

2.3.1. Sampling strategy

A multi-stage stratified sampling design was adopted, in accordance with ASTM D5231-92 (2019) standards and World Bank recommendations (Kaza et al., 2018).

Strata were defined based on:

- Municipality;
- Type of neighborhoods (planned, semi-planned, informal);
- Socio-economic level (low, medium).

2.3.2. Site selection

In each municipality:

- Five neighborhoods were selected;
- Within each neighborhood, three collection points were identified (transfer dumps, pre-collection points, and volunteer households).

This corresponds to a theoretical total of 75 collection points per campaign.

2.3.3. Sample size

At each collection point, a gross sample of 80 to 120 kg of waste was collected, in accordance with methodological recommendations (ASTM, 2019; Tchobanoglous et al., 2014). Samples were subsequently reduced by successive quartering until an analytical sample of 20 to 30 kg was obtained.

2.4. Collection, transport, and storage of samples

Waste collection was carried out manually using shovels, rakes, reinforced plastic bags, and standardized containers. Operators were equipped with personal protective equipment (PPE), including gloves, boots, masks, and protective suits, in accordance with safety standards recommended by the World Health Organization (WHO, 2017).

Samples were transported to a temporary sorting and characterization site located near the study areas, in order to minimize mass losses and physicochemical changes related to transport time.

The maximum time between collection and sorting did not exceed 12 hours.

2.5. Manual sorting procedure and categorization

Manual sorting was carried out on plastic tarpaulins, following the standard gravimetric sorting method (Tchobanoglous et al., 2014; UNEP, 2018).

The retained categories were:

- Biodegradable organic waste;
- Plastics;
- Paper and cardboard;
- Ferrous and non-ferrous metals;
- Glass;
- Textiles, wood, and leather;

- Fine and inert fractions (sand, ash, rubble).

Each fraction was weighed separately using electronic scales (accuracy ± 50 g). The masses were expressed as a percentage of the total sample mass to obtain mass composition percentages.

2.6. Determination of moisture content

Moisture content was determined using the gravimetric oven-drying method (105 °C for 24 h), in accordance with ASTM (2019) and AFNOR standards.

Moisture content (H, %) was calculated as:

$$H = [(M_{wet} - M_{dry}) / M_{wet}] \times 100$$

This method makes it possible to assess the influence of seasonality on the biological and energy-related properties of municipal solid waste (Hoornweg & Bhada-Tata, 2012; UNEP, 2018).

2.7. Determination of bulk density

Bulk density was measured by filling a standardized container of known volume ($\mathbf{V = 0.1\ m^3}$) with uncompacted waste and then measuring the corresponding mass.

Bulk density (ρ, kg/m^3) was calculated as:

$$\rho = M / V$$

Bulk density is an essential parameter for the design and sizing of collection, transport, and storage equipment (Tchobanoglous et al., 2014).

2.8. Measurement of pH and electrical conductivity

pH and electrical conductivity were measured on an aqueous extract (solid/liquid ratio 1:10), in accordance with the NF EN 13037 standard.

Measurements were performed using a pH meter and a conductivity meter, calibrated daily.2.8 Determination of organic matter content (loss on ignition)

Organic matter content was determined by loss on ignition at 550 °C for 4 hours.

$$OM\ (\%) = [(M_{dry} - M_{ash}) / M_{dry}] \times 100$$

This method is widely used to estimate waste biodegradability (UNEP, 2018; Sakouvogui et al., 2023).

2.9. Determination of carbon, nitrogen, and C/N ratio

Total carbon was estimated from organic matter content, while total nitrogen was measured using the Kjeldahl method.

The C/N ratio, a key indicator for composting, was calculated as:

$$C/N = C_{total} / N_{total}$$

A C/N ratio between 20 and 30 is considered optimal for composting (Tchobanoglous et al., 2014; UNEP, 2018).

2.10. Estimation of the lower heating value (LHV)

The lower heating value (LHV) was estimated based on mass composition and moisture content, using empirical equations proposed by Hoornweg and Bhada-Tata (2012) and Kaza et al. (2018).

3. Results

Estimated quantities and per capita waste generation

Based on field sampling campaigns and regional references (Hoornweg & Bhada-Tata, 2012; Kaza et al., 2018), the average per capita generation of municipal solid waste in the studied municipalities is estimated to range between 0.45 and 0.70 kg per capita per day, with variations related to socio-economic level and urban density.

The municipalities of Kagbelen and Kountia show slightly higher values (0.60–0.70 kg/capita/day) due to rapid urbanization and higher commercial activity, while Coyah and Dubréka display more moderate values (0.45–0.60 kg/capita/day).

Overall mass composition of municipal solid waste

Average composition across all municipalities

Gravimetric sorting results show a strong dominance of the biodegradable organic fraction, confirming the typical profile of West African cities (UNEP, 2018; Sakouvogui et al., 2023).

Table 1 Overall average mass composition (%)

Fraction	Dry season	Rainy season
Organic matter	46.8 ± 4.2	52.6 ± 4.8
Plastics	20.1 ± 3.1	17.4 ± 2.9
Paper/Cardboard	8.2 ± 1.9	6.5 ± 1.6
Metals	4.3 ± 1.2	3.9 ± 1.1
Glass	3.8 ± 1.0	3.2 ± 0.9
Textiles/Wood	6.1 ± 1.5	5.4 ± 1.4
Inert/Fines/Miscellaneous	10.7 ± 2.6	11.0 ± 2.8

A statistically significant increase ($p < 0.05$) in the organic fraction is observed during the rainy season, associated with higher moisture content and faster biodegradation of organic waste."

3.1. Inter-municipal variability in waste composition

3.1.1. Organic fraction by municipality

Table 2 Organic fraction by municipality (%)

Municipality	Dry season	Rainy season
Coyah	44.5	50.2
Dubréka	45.8	51.7
Sanoyah	47.2	53.5
Kagbelen	48.9	55.1
Kountia	47.8	54.3

Municipalities undergoing recent urbanization (Kagbelen and Kountia) exhibit higher proportions of biodegradable waste, reflecting a larger share of food waste and plant residues.

3.2. Moisture content

3.2.1. Overall moisture content

Average moisture content is significantly higher during the rainy season.

Table 3 Average moisture content (%)

Parameter	Dry season	Rainy season
Average moisture	41.3 ± 5.2	56.8 ± 6.1

This increase is attributed to:

- Infiltration of rainwater into the waste;
- A high proportion of fresh organic waste;
- The absence of waste containment systems.

3.3. Bulk density

Table 4 Bulk density (kg/m^3)

Season	Average density
Dry season	385 ± 45
Rainy season	462 ± 52

The higher bulk density observed during the rainy season is directly related to increased moisture content, which has a significant impact on transport and storage costs.

3.4. pH and electrical conductivity

Table 5 pH and electrical conductivity

Parameter	Dry season	Rainy season
Mean pH	6.9 ± 0.4	6.4 ± 0.5
Conductivity (mS/cm)	3.1 ± 0.8	3.8 ± 1.0

The slight acidification observed during the rainy season reflects the intensification of fermentation processes in biodegradable waste.

3.5. Organic matter content (OM)

Table 6 Organic matter (%)

Season	OM (%)
Dry season	48.5 ± 6.0
Rainy season	55.9 ± 6.8

These values confirm a strong potential for biological recovery (composting and anaerobic digestion).

3.6. Carbon, nitrogen, and C/N ratio

Table 7 C/N ratio

Season	Mean C/N
Dry season	22.8 ± 3.4

Rainy season	20.6 ± 3.1

The observed C/N ratios are favourable for composting, falling within the optimal recommended range (Tchobanoglous et al., 2014; UNEP, 2018).

3.7. Lower heating value (LHV)

Table 8 Estimated LHV (MJ/kg)

Season	**Mean LHV**
Dry season	8.4 ± 1.2
Rainy season	6.7 ± 1.1

The decrease in LHV during the rainy season is directly related to increased moisture content and a higher proportion of organic matter.

3.8. Synthesis of results and technical implications

The results highlight:

- A structural dominance of the organic fraction (> 50% in the rainy season);
- High moisture content limiting direct energy recovery;
- Physicochemical parameters favourable for composting;
- A moderate potential for recycling plastics and paper.
- These characteristics are consistent with the profiles reported for other West African cities (Hoornweg & Bhada-Tata, 2012; Kaza et al., 2018; UNEP, 2018)."

4. Conclusion

The present study provides a detailed, integrated, and scientifically robust characterization of municipal solid waste (MSW) in the northern municipalities of Conakry (Coyah, Dubréka, Sanoyah, Kagbelen, and Kountia), based on an approach combining gravimetric sorting and physicochemical analyses, while explicitly accounting for seasonal variability between the dry and rainy seasons. This study represents one of the few recent investigations to offer a structured database on the composition and properties of MSW in these rapidly growing peri-urban municipalities, thereby helping to fill a critical information gap for strategic waste management planning in Guinea.

The results consistently confirm, in line with regional and international literature, the structural predominance of the biodegradable organic fraction, representing on average nearly half of total waste and exceeding 50% during the rainy season. This dominance of organic waste reflects dietary habits, the high proportion of kitchen waste, as well as the significant contribution of plant residues from markets, peri-urban agriculture, and green spaces. This configuration gives MSW in the studied municipalities a highly biodegradable profile, typical of West African cities, as reported by Hoornweg and Bhada-Tata (2012), Kaza et al. (2018), and the United Nations Environment Programme (UNEP, 2018).

Seasonality emerges as a key determinant of waste physicochemical dynamics. The rainy season is associated with a significant increase in moisture content, bulk density, and the relative proportion of organic matter, which intensifies fermentation processes and biological degradation. These seasonal changes have direct implications for the operational performance of collection and transport systems, by increasing the mass transported for a given volume, as well as for technological treatment options, by reducing the potential for direct energy recovery and strengthening the relevance of biological treatment pathways such as composting and anaerobic digestion.

Recommendations

The results of the analysis of the composition and physicochemical characteristics of municipal solid waste in the northern municipalities of Conakry highlight the need for a strategic reorientation of local waste management policies toward an integrated approach, based on resource recovery, improved governance, and optimization of operational performance. The predominance of the organic fraction, combined with favourable physicochemical parameters (C/N ratio, pH, organic matter content), justifies prioritizing biological recovery pathways, particularly composting and, in

the medium term, anaerobic digestion, in order to significantly reduce landfill disposal volumes and produce organic amendments useful for peri-urban agriculture.

In parallel, the gradual introduction of source separation, at a minimum into two streams (biodegradable waste and dry recyclable waste), appears as a key lever to improve the quality of recyclable materials and reduce contamination of recoverable fractions. This measure should be accompanied by the structuring of local recycling value chains, particularly for plastics, paper and cardboard, metals, and glass, through the establishment of sorting centres, the development of public–private partnerships, and the integration of informal waste pickers into formalized systems.

Adapting collection and transport systems to strong seasonality also constitutes a major operational priority. The increase in moisture content and waste density during the rainy season requires adjustments in collection frequency, the use of covered containers, and route optimization, in order to limit nuisances, additional costs, and public health impacts. Complementarily, the institutionalization of periodic waste characterization should be integrated into the regular mandates of municipal services, in order to ensure the availability of up-to-date data for infrastructure sizing and performance assessment.

From an institutional and financial perspective, strengthening local governance and inter-municipal coordination is recommended, by clarifying roles and responsibilities, pooling investments, and enhancing the technical capacities of municipal services. System sustainability also requires the establishment of durable economic mechanisms, including appropriate user fees, the mobilization of innovative financing, and the valorization of environmental benefits (methane emission reductions, carbon credits).

Finally, the success of these reforms depends on the commitment and participation of communities and stakeholders. It is therefore essential to strengthen awareness-raising actions, environmental education, and community participation, while integrating waste management into urban development policies, flood control strategies, and the promotion of a circular economy. In this perspective, the promotion of applied research and local innovation will make it possible to continuously adapt solutions to the socio-economic and environmental realities of the northern municipalities of Conakry**.**

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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