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ASSESSING SOLID WASTE CHARACTERIZATION AND TREATMENT OPTIONS AS PART OF WASTE MANAGEMENT IN KANO CITY, NIGERIA

Elizabeth D. Jenkwe* and F. Ujoh

Department of Geography and Environmental Management,
University of Abuja, Nigeria
*Corresponding Author: elizabethjenkwe@uniabuja.edu.ng, elizabethjenkwe@gmail.com

Abstract

In terms of amount and diversity, the continual creation of Municipal Solid Waste (MSW) is a global problem. The community's financial situation, the time of year, population, culture, and way of life all impact MSW. Nigeria, in particular, is now grappling with the threat of an increase in the quantity of MSW in its main cities. However, it is primarily concerned with its collection, transportation, and disposal, ignoring the possibility of material recovery from MSW for recycling. On that basis, the study aims to describe MSW and examine the treatment methods available from recognised dumpsites and at the household level in Kano State Municipal Area Council Kano, Nigeria, in order to promote sustainable and efficient MSW management. The SWA-Tool approach was employed in this study, created by an EU-funded project to classify mixed household garbage in cities with no prior expertise in waste characterisation. More sub-fractions were examined while keeping REMASAB's basic categorisation into fractions. A granulometric analysis was introduced to get the data required for the evaluation of mechanical separation methods and the administration of questionnaires for data collection. The findings indicate that income level significantly affected the elements of MSW created at the district level. Finally, food waste/organics and plastic garbage are the most prevalent MSW types in Kano, Nigeria. Characterisation of MSW is required for long-term impact and sustainable solid waste management strategies to develop an acceptable and efficient waste-management system for society.

Keywords: Characterization; Household; Municipal Solid Waste; Treatment Options, Waste Management

Introduction

In both developing and developed countries, solid waste is a major environmental issue (Abdel-Shafy and Mansour, 2018). Most undeveloped countries have only recently begun to improve their solid waste management procedures. Inadequate solid waste management causes difficulties that harm human and animal health and cause economic, environmental, and biological losses (Sharholy *et al.*, 2008; Nguyen, Dai Dinh, Dong and Le, 2022). Unhealthy waste accumulation in any location or environment provides reasonable breeding grounds for vermin and flies, both of which are disease vectors and can also detract from the aesthetics of the environment, posing a health risk to the general public (Jenkwe, 2023). If waste is adequately handled, it will prevent people from incurring excessive costs rather than creating profit. Human activities are best carried out in a safe and healthy environment where trash is correctly disposed of and managed. The enormity of the solid waste problem is difficult to understand, yet it can

be related to population growth (Afon and Okewole, 2007).

Exploding populations have resulted in a heavily congested environment in which residences are closer together than ever before, resulting in the dumping of more garbage on the streets and the medians of main roadways, as suggested in the study of Magaji and Jenkwe (2020). This is primarily because waste receptacles beside highways need to be increased. Annually, thousands of people die due to diseases caused by improper waste disposal in the environment.

The threat of solid waste is a massive problem in the Kano State Metropolis. In Kano's commercial centres, marketplaces, and streets, solid waste has emerged as one of the most significant problems amid a host of other issues plaguing the metropolis, which this research is set to solve.

Solid waste and management

Solid waste is a non-gaseous material that humans have created. Residues from home, commercial, industrial, and agricultural operations can be residues (Leton, 2007). Municipal Solid Waste is those undesired items created from society's operations and abandonment. These are by-products of manufacturing processes or when materials and items are discarded after use in the residential or business sectors (Olukanni and Mnenga, 2015). According to Agori (2010), 87% of Nigerians employ ineffective waste disposal techniques, which provide a nuisance, an unattractive look, a stench (an air pollutant), and a breeding ground for pests and illnesses (Adewumi, 2001). Poor waste management has harmed public health in several developing countries. Indiscriminate solid waste disposal is a threat to any country. However, underdeveloped and developing countries are particularly vulnerable, with a large percentage of illegal trash dumped on roads or road sites, permitted dump sites, waterways, drainage systems, or open areas, all of which harm the environment (Kawai and Tasaki, 2016). Indeed, when solid waste is not collected and disposed of correctly, it poses a range of health problems and has a severe influence on fauna and flora as well as the environment (Oyebola, 2009; Ejaz *et al.*, 2010; Ogwueleka, 2009).

The Metropolitan Transfer Station (2017) states the following as the effects of municipal solid waste:

1. Soil Contamination
2. Water Contamination
3. Air Contamination
4. Climate Change-Induced Extreme Weather

Solid waste management is the collection, transportation, processing, recycling, or disposal of waste materials created by human activity to reduce the negative impact of improper disposal on human health and local aesthetics and convenience. Home garbage management is the most challenging aspect of dealing with rural solid waste (Asgari *et al.*, 2019). It is concerned with waste management, including waste generation, storage, collection, transfer, transportation, processing, and disposal. Waste generated by households, hospitals, industries, and commercial centres contributes significantly to environmental obscenity and nuisance, which are hazardous to human life.

Decomposed garbage generates carbon dioxide (CO_2) and methane gas (CHU), which contributes to global warming; according to Lee and Jones (1991) and Dauda and Osita (2003), garbage disposal is a multifaceted issue that may be attributed to a variety of factors, including the government's inadequate institutional framework for waste management, the inherent rural nature of most urban residents, the status of public health, and high urban poverty, to mention a few. In particular, municipal corporate entities' incapacity to offer the required public service in metropolitan regions is commonly cited. (Moftah, Marković, Moftah and Nesseef, 2016; Raje, Wakhare, Deshpande and Bhide, 2001; Mor *et al.*, 2006; Ferronato, and Torretta, 2019). Few public education campaigns educate the

public about the consequences of indiscriminate garbage disposal and dumping. The primary purpose of this study is to look at municipal solid waste characterisation and treatment options for Kano City's solid waste management.

Separating total waste at a particular site into numerous classifications, each measured independently and aggregated to get the overall quantity, is known as characterisation (Ugwu *et al.,* 2020; Aderoju *et al.,* 2020). Characterisation can be done through visualisation or hand sorting. However, the latter yields a more accurate result. Solid waste can be characterised into the following groups in Table 1.

Table 1: Characterization of solid waste

Sources	Typical waste generators	Examples of solid wastes
Residential Waste/ Organic Waste	Household, store, hotels, restaurants, offices and marketplace	Food wastes.
Institutional/ Combustible Waste	Household, Hospital, offices, stores, hotels	Paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes.
Industrial Waste	New construction sites, road repair, renovation sites, demolition of buildings	Packaging, textile, chemical waste, construction and demolition materials, metal, wood, steel, concrete, ashes nuclear dirt.
Process (manufacturing) Waste	Manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Hazardous waste, batteries, chemical waste, scraps materials, oil, medical waste, mining waste.
Agriculture Waste	Plant and Animal farms	Agricultural wastes such as , hazardous wastes such as pesticides, fertilizers and slaughter waste

Source: Yildiz *et al.* (2012)

Treatment options

Current treatment solutions help to minimise the amount of solid waste that must be landfilled while also collecting and utilising as much material as feasible from discarded waste as a resource. Different methods are used to treat solid waste, and the properties of the waste determine the best option, the amount of land available, and the disposal cost. Tillman et al. (1998) described waste treatment as any activity in which the properties and components of waste are transformed. The solid waste treatment options include:

Incineration: A controlled combustion process produces gases and residue containing non-combustible material by burning solid waste in excess air (oxygen) at high temperatures of about 1000 ° C and above.

Compaction: The trash is compressed or packed. It also breaks down massive or fragile trash objects.

Pyrolysis: This is the thermal decomposition of waste in the absence of air to create char, pyrolysis oil, and syngas—for example, the conversion of wood to charcoal.

Gasification: is a process in which municipal solid waste is partially burned in the presence of oxygen but at a smaller proportion than necessary for complete combustion to produce combustible gases (fuel gas) rich in carbon monoxide and hydrogen, similar to how coal is transformed into town gas. (Dernbach and Henning, 1987).

Composting: Composting is the process of bacterial degradation of organic components of municipal trash that results in the development of humus or compost. It is also known as biodegradation, and it aids in the disposal of solid waste, the disposal of night soil, and the formation of excellent manure for crops (Adewumi *et al.,* 2005).

Recycling: comprises reusing specific waste components that may have economic worth. Recycling saves resources, decreases industrial energy use, and lowers pollution (Troschinetz and Mihelcic, 2009).

On this note, this study aims to assess municipal solid waste characterisation and the treatment options opened in Kano City, Kano, Nigeria, as well as highlight the impact of municipal solid waste on the environment and its occupants in this part of the country. It has all the elements, but only a few studies have been conducted in this study area.

Methodology

The research area (Figure 1) for this research study is in the northern part of Nigeria. According to the 2016 National Bureau of Statistics estimates, Kano state is the largest northern state in Nigeria by population, and its capital, Kano City, is the second largest in the country. The National Population Commission and National Bureau of Statistics 2016 pegged Kano state's estimate at 13,076,892, with a land area of 20,131 km^2. It is located in the south of the Sahara Desert and spreads to the south of the Sahel with coordinates 11º7471'N and 8º5247'E. The city lies near the Kano and Challawa rivers that flow from the southwest, converge and form the River Hadejia, which flows into Lake Chad to the east. Kano City has an estimated population of 4,103,000 people. It lies between latitude 12º.00 'N and longitude 8º.31667' E. It sits 481 metres above sea level, with a Tropical Savannah Climate, and as such, it is scorching for most of the year, with its peak in April. It encompasses a 499 km^2 land area.

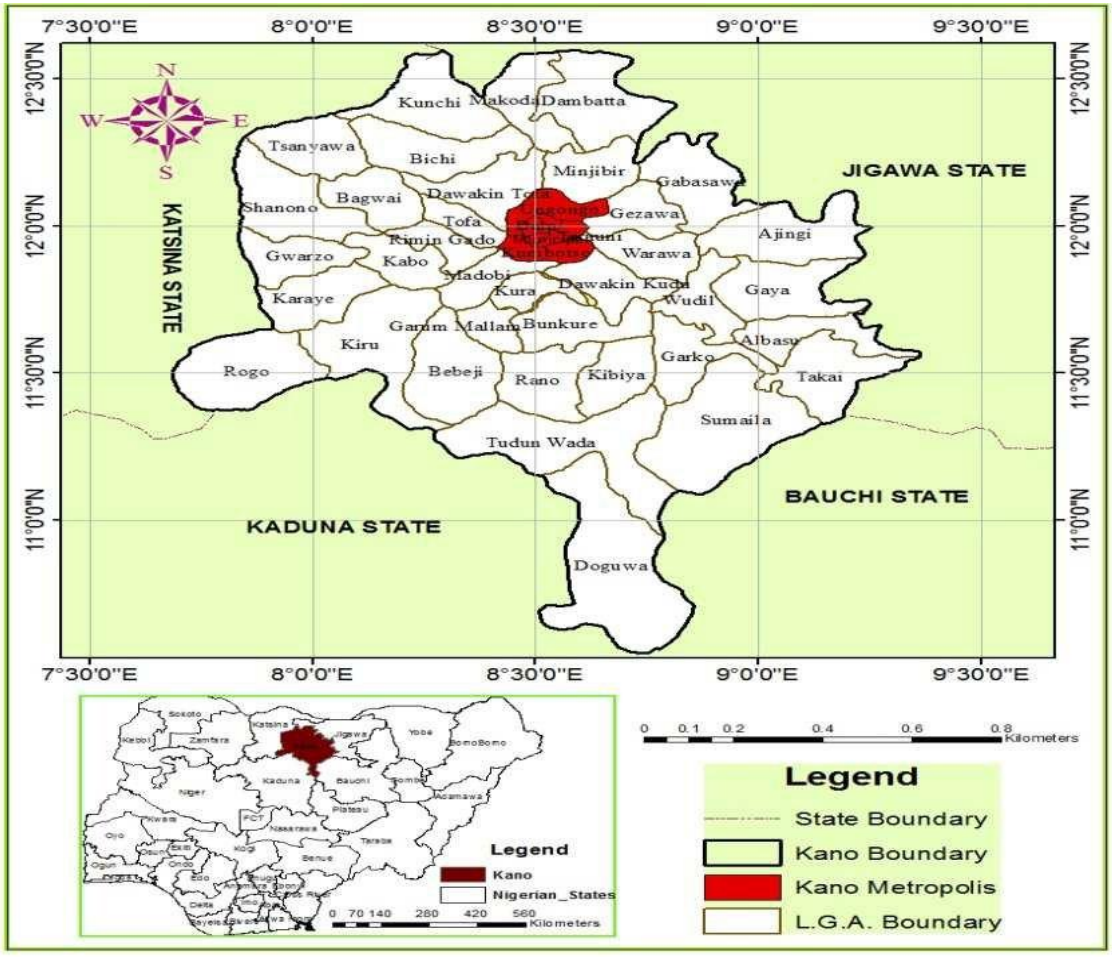


Figure 1: Map of Kano State showing Kano Metropolis (the study area)
Source: Adamu *et al.* (2017)

More sub-fractions were analysed to get a better insight into waste flows, to make prognostics of recoverable fractions, and to elaborate on financial scenarios, maintaining the initial classification into fractions by REMASAB. A granulometric analysis was added to get the data necessary to evaluate mechanical separation options. This is especially important for mixed household waste since it is not realistic to assume that separate collection at the source would achieve the required performance in the short term, even if introduced in Kano by REMASAB. Sieving was done manually with wooden sieves with wire mesh. The orifices were 20 mm and 80 mm, respectively. Plates 1 and 2 show the sieves used for granulometric analysis.



Plate 1: 20 mm sieve



Plate 2: 80 mm sieve

Collecting and weighing garbage was an essential distinction in the solid waste characterisation. Aggregated samples from each stratum were sorted for the current investigation. This adjustment reduced measurement mistakes, which are more critical with small samples. An electronic balance was utilised to improve measurement sensitivity and decrease mistakes, especially for small sub-fractions.

Private garbage collection operators were hired to send black waste bags to selected homes and collect, weigh, and register garbage for each household separately. During the characterisation, questionnaires were used, with a cell added to record the number of people residing in the home. The total number of households involved in the assessment was 209 houses, and the overall number of inhabitants was 1330 people.

Statistical Analysis of the Results

Statistical analysis is required to establish how trustworthy the waste characterisation data is.

The Table 1 summarises the samples collected for each stratum and day. Grey cells indicate that no sample was obtained from a given place that day; red cells indicate that the sample had to be discarded owing to measurement or sampling errors.

For the statistical analysis of the reliability of data obtained by the waste characterization, the study used the SWA-Tool methodology, developed by an EU-financed project for the characterization of mixed household waste in cities with no experience in waste characterization.

Table 3 indicates that the bulk of garbage collected in high-density locations is non-recyclable and non-compostable. The fraction of recyclable materials is slightly more significant than that of organic material

in the two other levels. The proportion of recyclable material in low-density locations is the lowest of the three strata. As would be expected, rich people are more wasteful than poor individuals. The amount of hazardous waste is meagre. Chemical waste has not been found. There was no infectious waste or sharps identified in the medical garbage. All batteries separated during waste characterization are Chinese Tiger Head zinc-alkaline batteries. There were no heavy metal-containing batteries discovered.

Table 2: Samples of the waste characterization

Date	High density (Kg)	Medium density (Kg)	Low density (Kg)	Fruit market (Kg)	Vegetable market (Kg)	Sub-total per day
10/04/2020	150.14		207.84			357.98
11/04/2020	89.53	70.35	123.66			283.54
12/04/2020	121.34		147.29			268.63
13/04/2020	91.98	89.20	144.64			325.82
14/04/2020	78.19	126.85	110.06			315.10
15/04/2020	81.95	56.16	126.69			264.80
16/04/2020		80.55	94.45	305.53	245.83	771.35
Sub-total per area	613.13	423.11	954.63	305.53	245.83	
Total						**2,587.22**

Table 3: Summary of Waste Composition

Waste Type	High density (Kg)	Medium density (Kg)	Low density (Kg)
Paper	2.17	2.50	2.63
Textile	4.78	1.68	1.83
Plastic	16.60	11.95	11.06
Glass	0.13	0.11	0.60
Metal	0.11	0.95	0.53
Hazard waste	1.32	0.58	0.14
Organic waste	20.26	39.97	39.41
Others	8.06	11.47	5.27
Processing Fine	46.56	30.79	38.54
Overall compostable	22.43	42.47	80.57
Overall recyclable	12.34	10.92	9.07

Statistical Parameters for Waste Composition Analysis in Kano

The Table 4 summarises the significant conclusions of the statistical study for evaluating waste composition.

The main parameters to judge the results' reliability are the confidence interval and the coefficient of variation.

The coefficient of variation is the ratio of the standard deviation to the mean:

$$\text{var coeff}(xi) = 100 * s / x, \quad \text{Equ. 1}$$

The confidence interval expresses the maximum and minimum values between which the result is to be expected with a probability of 95 %:

$$Ic = x +/- (t\Theta; n-1 * \text{var coeff}(xi))/ \sqrt{n) \quad \text{Equ. 2}$$

In this investigation, an exhaustive analysis of refuse fractions was conducted, focusing on their coefficients of variation, mean values, standard deviations, and confidence intervals. The results in Table 4 illuminate the distinctions and characteristics of different types of refuse materials, data critical for developing effective recycling and waste management strategies.

This study possesses several merits and demerits. A notable strength is the extensive variety of refuse materials analysed, which provides a comprehensive picture of trash composition. Furthermore, coefficients of variation can be employed to quantify the variability present within each waste type. However, the study's primary limitation is that it needs to be more relevant to broader environmental and waste management

frameworks. Additional factors that may impact waste composition, including socioeconomic and regional disparities, are overlooked. Furthermore, it should be noted that the study is based on a specific dataset, which may differ from general waste management scenarios.

The characterisation of solid waste is the initial stage in the design of solid waste management. Knowing the content of the waste enables the development of strategies for waste separation, collection, and collection frequency for recycling. The findings of this investigation revealed two crucial points:

1. The significant recovery potential of trash for recycling and
2. The problem that waste management entails.

Table 41: Statistical parameters for waste composition analyses in Kano (3 strata consolidated)

Fractions	Sub-fractions	Mean (Kg)	Standard deviation (Kg)	Confidence interval		Coefficient of variation (%)
				(Kg)	(% of the mean)	
Paper	Clean Paper	0.32	0.64	1.17	364.08	1.99
	Soiled Paper	2.12	1.11	0.31	14.56	52.53
Textile		2.57	2.66	0.61	23.71	103.60
Plastic	PET	1.60	1.56	0.57	35.78	97.40
	HDPE film	0.75	0.54	0.42	56.44	72.33
	HDPE 3D	0.76	1.20	0.93	123.62	159.13
	PVC	0.07	0.26	2.07	2,766.49	352.58
	LDPE clear	4.32	2.01	0.27	6.32	46.52
	Recycled	3.12	2.78	0.52	16.77	89.17
	PP film	1.38	1.57	0.67	48.28	113.73
	PP 3d	0.64	1.03	0.94	146.13	160.11
	PS	0.30	0.41	0.80	268.82	136.44
Glass	Transparent	0.27	0.48	1.03	377.36	175.88
	Coloured	0.03	0.12	2.56	9,132.19	435.30
	Flat	0.05	0.18	2.24	4,778.12	381.70
Metal	Fe Metal	0.36	0.41	0.66	180.00	111.65
	Al containers	0.07	0.12	0.98	1,306.91	166.70
	Al Film	0.07	0.16	1.38	2,061.62	235.67
Hazardous waste	WEEE	0.06	0.15	1.41	2,323.87	240.00
	Medical waste	0.38	0.91	1.42	375.98	241.77
	Batteries and accumulators	0.16	0.50	1.83	1,154.88	312.28
Organic waste		33.16	12.25	0.22	0.65	36.93
Baby diaper		2.71	3.19	0.69	25.48	117.61
Shoes		0.48	0.57	0.69	144.31	118.28
Ceramic		0.40	0.69	1.02	258.26	174.51
Complex/composite	Packaging	0.31	0.38	0.71	226.62	120.42
	Other	0.28	1.19	2.46	867.99	418.82
Other		2.63	3.93	0.88	33.45	149.57
Processing Fines		40.62	14.58	0.21	0.52	35.90

The statistical analysis makes sense mainly for the most relevant (sub-) fractions, organic waste, fines, dirty paper, and LDPE bags because the inaccuracy grows with smaller sub-fractions. In the instance of the Kano analysis, the confidence interval for organic waste is <0.5 kg for four fractions: organic waste, fines, LDPE bags, and dirty paper, and it is <1% of the mean for organic waste and fines. This is an acceptable conclusion, albeit the confidence interval becomes much more

crucial for the smaller and more heterogeneously distributed sub-fractions.

The coefficient of variation permits judgements about the heterogeneity of the mother sample, i.e., the Kano population. The coefficient of variation for the three most essential components, organic waste, fines, and LDPE bags, ranges from 35.90% to 52.53%. The table above shows the sampling error concerning the variation coefficient obtained during the present characterisation process and the sampling error.

The research findings align with specific recommendations in the study of Tsuchimoto and Kajikawa (2022) and Faraca and Astrup (2019). The discovery of substantial coefficients of variation in classifications such as coloured glass and PVC plastic aligns with prior research that emphasised the subjectivity of these materials due to elements like consumer behaviour and product design. In contrast, the relatively low coefficients of variation observed in categories such as pure paper and organic waste are consistent with the generally accepted notion that these materials possess a more uniform composition, as opined in the studies of Lohri *et al.* (2017) and Edjabou *et al.* (2015).

Also, prior research has not adequately documented the exceptionally high coefficient of variation in the "Other" category of complex/composite materials. This suggests that further investigation is required to ascertain this variation's underlying causes.

The economic value of waste to wealth

When they are correctly managed, pollution reduction, energy savings, social benefits, and economic benefits are the significant indicators that will be used to assess the benefits of waste-to-wealth operations. Organic fertiliser is intended to be the primary source of income. Palletised plastic is also being sold to select recycling organisations inside and outside the state. The recycled metal scraps will be sold to the state's government, namely the Ministry of Works and Public Infrastructures. Other recyclable items inside Kano are sold to scrap merchants or recycling plants. This has piqued the curiosity of Kano's small-scale businesses, with polyethene trash recyclers sprouting up and scrap traders proliferating.

Conclusion and Recommendations

Waste generation is an everyday occurrence. Its management should be simple, provided suitable measures are used. Today's major problem confronting the global community is transforming the industrial economy into a closed system more akin to the biosphere. This would save energy while also reducing waste and pollution and lowering prices. In a nutshell, it would improve sustainability by creating jobs and recovering costs. The most feasible approach to the country's sustainable environmental development is to guarantee that our resources, including trash, provide the most environmental and economic benefit while not jeopardising future generations' capabilities.

Finally, the study proves the importance of waste categorisation in solid waste management and profit production for the state. This has not only made Kano more ecologically friendly, but it has also provided jobs for operators. The following things could be upgraded for future operations:

1. The general population should be informed about waste reduction strategies at home. Waste reduction success mainly depends on education, increased public awareness, and people's desire to modify wasteful practices. As a result, waste education should come first.
2. Source separation efforts at the household level should be performed to reduce the cost of separation at recycling facilities while also increasing the amount and quality of recyclables.
3. Kano State's waste-to-wealth initiatives should include manufacturing plastic lumber. Plastic timber is another essential commodity made from commingled waste plastic. Plastic lumber is intended

to outlive traditional wood products and is said to have advantageous features such as high strength, durability, and rot resistance.

4. Scavenging should be appropriately organised to reap the most economic rewards from such operations while protecting the health and safety of participating individuals.

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