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Generation and composition of solid waste in low-income areas of Jos, Plateau State, Nigeria

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Abstract

This study was carried out to determine the composition of solid wastes generated by some households in low-income areas of Jos Plateau State. Point source daily collection of household wastes from selected homes that were initially identified and categorized as low-income households were carried out for one week. The collected waste samples were weighed and sorted into food, ash/unburnt wood, plastic film/bags, fines, miscellaneous combustible, papers/cards, textiles, waste from electrical and electronic equipment (WEEE), glass, metals, dense plastic, garden waste and others. The components of these solid wastes were further classified into biodegradable (65.2%), recyclable (13.2%) and residual (21.6%). Biodegradable materials in the waste stream per household ranged from 1.7 kg to 18.3 kg per week. The recyclable materials produced by households varied from 0.4 kg to 2.9 kg and residual waste ranged from 0.6 kg to 6.0 kg per week. Urbanization and population growth are solely responsible for high increasing rate of solid wastes. The average household size found in the study area is 6.3 compared to an average household size of 4.6 Nigeria Demographic and Health Survey and 5.5 for Jos – Bukuru metropolis.

Keywords: Generation; Components; Solid waste; Low- income area; Jos; Nigeria

1. Introduction

Solid waste refers to any type of garbage, trash, refuse or discarded material. It can be categorized according to where the waste is generated, for example as municipal solid waste, health care waste and e-waste. Over 2 billion tons of municipal solid waste are produced annually. Solid waste management starts from generation to collection, transport, treatment and disposal of waste. Challenges of solid waste management encompass for example poor waste collection and improper disposal such as in uncontrolled dumpsites with no measures to protect soil or groundwater (World Bank, 2020, Kaza et al, 2018).

Municipal solid waste, (MSW) is basically waste generated from different sectors of the society which include educational, household, health, commercial institution, public places, etc. (Agwuncha et al, 2022, Hoornweg & Bhada-Tata, 2012). Over time, economic activities and consumption practices have been a major factor in the generation of MSW (Romano and Molinos-Senante, 2020). In low- and middle-income countries, solid waste is often disposed on low-lying areas, as a result of poor regulation and this has enabled hazard related waste to be mixed with MSW which pose a harmful threat to both waste collectors, scavengers and to the environment (Agwuncha et al, 2022).

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Municipal solid waste has become an important issue in Nigeria. Piles of wastes are often found by roads, rivers and many other open spaces in cities, and this is causing significant planning and environmental problems (Gwom and Ijeoma, 2014). The characterization of generated waste is very important for the design of proper collection, selecting appropriate transportation equipment, energy transformation and it plans for the application of waste management (that is reuse, reduce, recover and recycle), Ugwu et al., 2020. Furthermore, the design of optimal disposal routes and methods, all depends on accurate quantification and compositional characteristics of MSW. The composition and quantity of solid wastes differ from place to place and from household to household. These differences are attributed to factors such as income level, socio-economic distribution, consumption and disposal habits of the people (Ugwu et al., 2020).

A report by Debnah et al. (2015) showed that there is going to be a significant rise in rate of solid waste generated per capita in a decade to come. Nigeria annual MSW from its 195 million population was quoted to be 32 million tonnes with only 20-30 % of these collected (Adeniran et al., 2017, Hoornweg & Bhada-Tata, 2012). The problem has been linked to factors such as weak environmental laws, inadequate funding, uncontrolled and rapid urbanization and industrialization and finally the use of open dumping and land filling methods for waste disposal (Agunwamba, 1998). Therefore, it has become very important for researchers to help determine the waste generated in selected towns and cities and its compositions, in order to develop effective management strategies (Amijo et al., 2008).

The composition of generated waste around the world varies significantly due to seasonal and lifestyle variation, geographical, and local legislation impact (Alqader and Hamad, 2012). Waste segregation is possible only when the characteristics are well known. The recyclable component collected and recycled while organic components are collected and used as compost. The inconsistency in data collection on the composition and quantity of solid waste in Jos as well as other townships in Nigeria has contributed to poor management of solid waste (Ejaro and Jiya, 2013). Therefore, the aim of this research is to quantitatively characterize the solid wastes generated by households in low-income areas in Jos town and determine the solid wastes that can be recycled.

2. Materials and methods

Household waste analysis was conducted within the study area in order to determine the quantity and composition of solid waste generated. Convenience sampling became necessary as some households selected for participation declined to take part in the questionnaire survey. This necessitated the change of plan in administering the questionnaire, to involve those who were at home and willing to participate in the research.

A week waste was collected from 74 households and characterized in the study area. Analysis was conducted for each individual house rather than bulk analysis, therefore generating more detailed results and analysis. Participating households completed questionnaire and information on their household characteristics and waste management behavior was collated. The key objectives of the study were to calculate the per capita generation rate of household waste from the study area, to determine the composition and relative quantities of the household waste stream, and identify priority materials for waste prevention.

2.1. Location of the study area

The city of Jos is made up of two local government areas, Jos North and Jos South. Figure 1 shows the location of low-income areas in the study area. The majority of housing in the low-income areas are compounds – these are buildings that has many single rooms, two rooms (a bedroom and a sitting room) or three rooms (two bedrooms and a sitting room) that can accommodate many families. For example, a compound can be shared by five different family units, with each family having their rooms but sharing facilities such as toilets and bathrooms, most often such houses have no kitchens.

The areas are unplanned with further observations showing that the buildings are old and closely packed together with no spaces between adjoining buildings such that the roof of one building overlaps the other (Figure 2). This constitutes a safety risk especially with respect to fire outbreaks. It also presents problems due to the lack of access roads for fire fighting vehicles and waste haulage trucks. The buildings are inferior and mainly made of cement and mud blocks with corrugated iron roofing sheets.

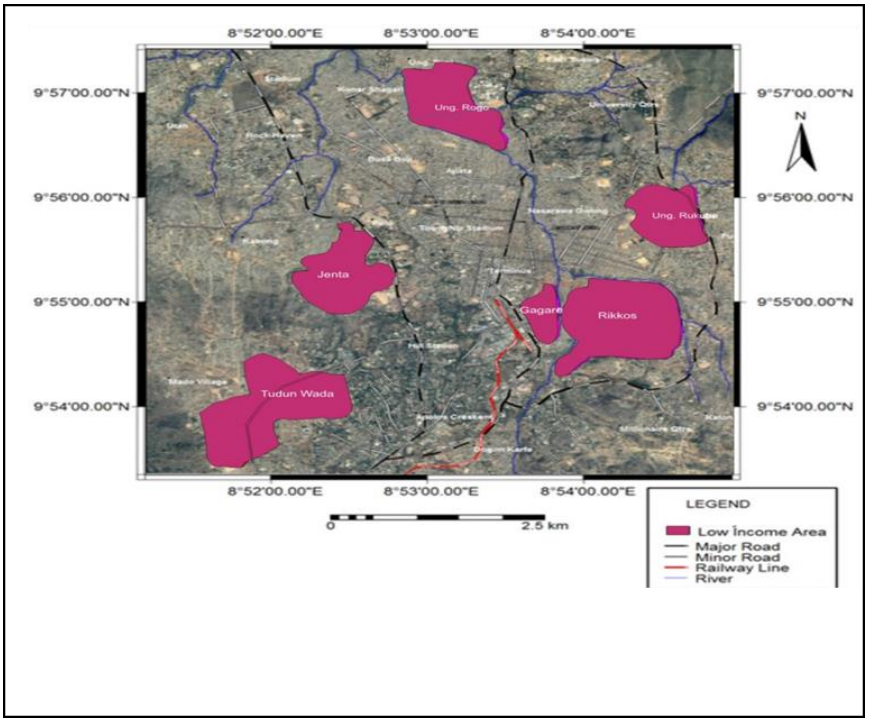

Figure 1 Location of low-income areas in the study area

Figure 2 Housing in close proximity in Jenta, Jos, Nigeria

3. Results and analysis

Table 1 and Figure 3 showed the overall waste composition of the study area by weights of solid waste collected. The total quantity of waste generated from the 74 households was 658.19 kg, with 466 persons residing in the households sampled, this equates to 0.47 kg/capita/day. The largest fraction was food waste which made up 29.2% of the total waste sampled.

The percentage of ash/unburnt wood in the waste stream was 18.4% reflecting the lifestyle of the households sampled. Plastic films/bags constituted 13.6% of the waste stream. This is due to plastic films/bags being prevalent in Nigeria to package items from markets and shops. In addition, the consumption of sachet water is common due to lack of good quality drinking water within the study area. In the methods adopted all plastic films and bags were grouped together, anecdotally it is estimated that 3/4 were single use plastic bags representing 10.2% of the overall waste stream. Fines,

consisting of soils and dust, made up 6.8%. The level might be due to most floors in compounds or homes not being cemented and made up of soil.

Table 1 Overall composition of waste sampled by weight and percentage

Category	Total waste (kg)	% of waste sampled
Food	192.1	29.2
Ash/unburnt wood	121.2	18.4
Plastic films/bags	89.7	13.6
Fines	44.7	6.8
Misc. comb	32.0	4.9
Paper/card	30.8	4.7
Textile	29.2	4.4
WEEE	24.3	3.7
Glass	23.7	3.6
Metals	21.0	3.2
Others	20.6	3.1
Dense plastic	17.9	2.7
Garden waste	10.9	1.7
Total	658.2	100.0

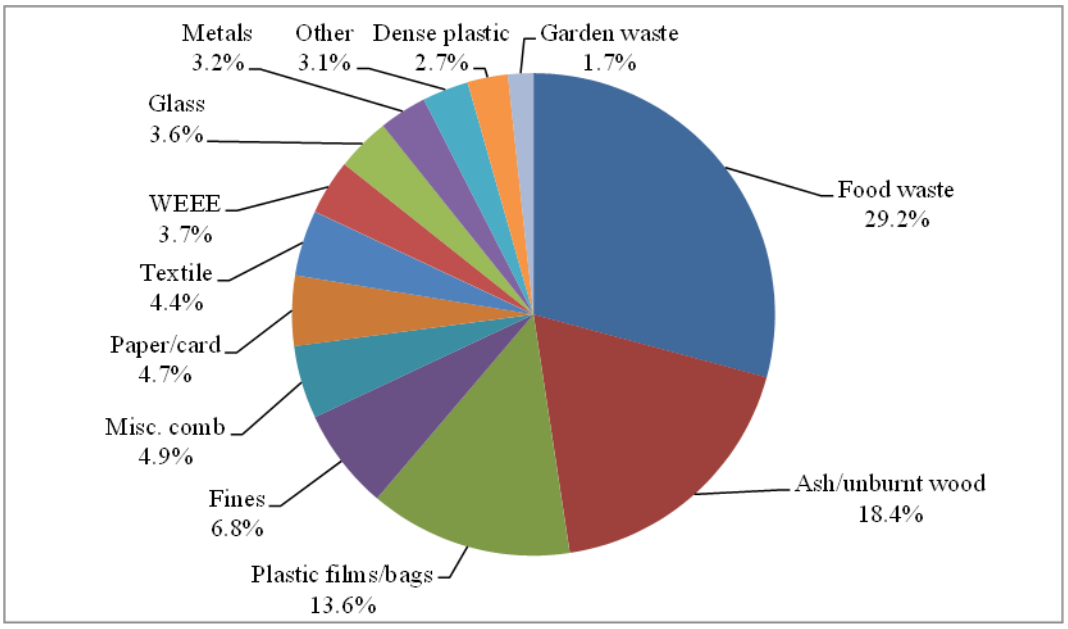

Figure 3 Overall waste composition of the study area by weight

Paper/card formed 4.7% of the waste stream made up mainly of newspapers, cartons and cardboard packaging. Textile made up 4.4% of the waste stream, the majority was offcuts from tailoring works, as some households had tailoring shops within their yards. Electrical and electronic waste materials were mainly broken phones and chargers, ear phones and calculators, and constituted 3.7% of the waste stream. Glass was 3.6% of the waste and made up of bottles, broken glass windows. 3.2% of the waste was metals of different kinds ranging from pieces of iron bars, nails, drink cans and pieces of roofing sheets (Figure 3).

Dense plastics made up of plastic bottles, plates, cups and pieces of broken buckets and jerry cans contributed 2.7% of the waste. The low percentage of dense plastic in the waste could be attributed to levels of reuse and recycling taking place (Figure 3). A wide variety of other materials were present including drugs, sanitary towels, nappies, and hazardous items like batteries. Miscellaneous combustibles included weave on (hair extensions) as some householders used their homes to do hair dressing/platting. Analysis of the variation of waste components is very important, as it helps municipalities and waste planners to plan on its management.

The food items were unprocessed with high moisture content consisting mostly of unavoidable waste materials. Figure 4 provides examples of unavoidable food waste sampled including bitter leaf stems, spinach stems, ogwu ribs, mango and yam peelings.

Figure 4 Examples of food waste sampled mainly stems and peelings.

Table 2 Maximum, minimum, mean and median quantities of waste components – kg/household/week

		Kg/household/week			
Category	**Classification**	**Maximum**	**Minimum**	**Mean**	**Median**
Food	Biodegradable	7.1	0.7	2.6	2.1
Ash/unburnt wood	Biodegradable	4.3	0.1	1.6	1.7
Plastic films/bags	Residual	5.2	0.4	1.2	1.1
Garden waste	Biodegradable	3.5	0.3	0.9	0.6
Fines	Biodegradable	2.1	0.1	0.7	0.7
Misc. comb	Residual	1.3	0.1	0.5	0.4
Paper/card	Recyclable	1.4	0.1	0.4	0.4
Textile	Biodegradable	1.1	0.1	0.4	0.4
WEEE	Recyclable	1.2	0.1	0.4	0.3
Glass	Recyclable	1.0	0.1	0.3	0.3
Others	Residual	1.2	0.1	0.3	0.3
Metals	Recyclable	1.1	0.1	0.3	0.3
Dense plastic	Recyclable	1.0	0.1	0.2	0.2

Table 2 shows the maximum, minimum, mean and median quantities of waste components from households in the study area, this was for the purpose of plotting boxplots. Figure 5 presents the boxplots of this waste components showing maximum/minimum, mean and median values. Boxplots provide comparative data on waste composition for the different waste groups. Waste materials were grouped into three broad categories based on their composition: biodegradable, recyclable and residual (Table 2 and Figure 5: Maximum, minimum, mean and median quantities of waste components – kg/household/week). 65.2% of the waste was classified as biodegradable, 13.2% recyclable and

21.6% residual. Figure 6 provides a breakdown of results for each household sampled. Biodegradable materials in the waste stream per household ranged from 1.7 kg to 18.3 kg per week. The recyclable materials produced by households varied from 0.4 kg to 2.9 kg and residual waste ranged from 0.6 kg to 6.0 kg per week.

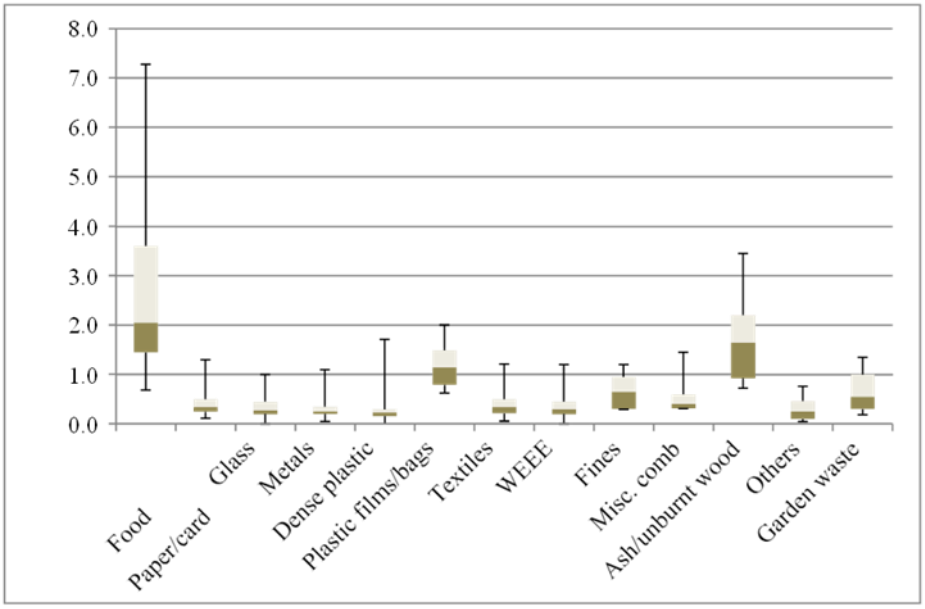

Figure 5 Box plots of maximum, minimum and median waste components sampled

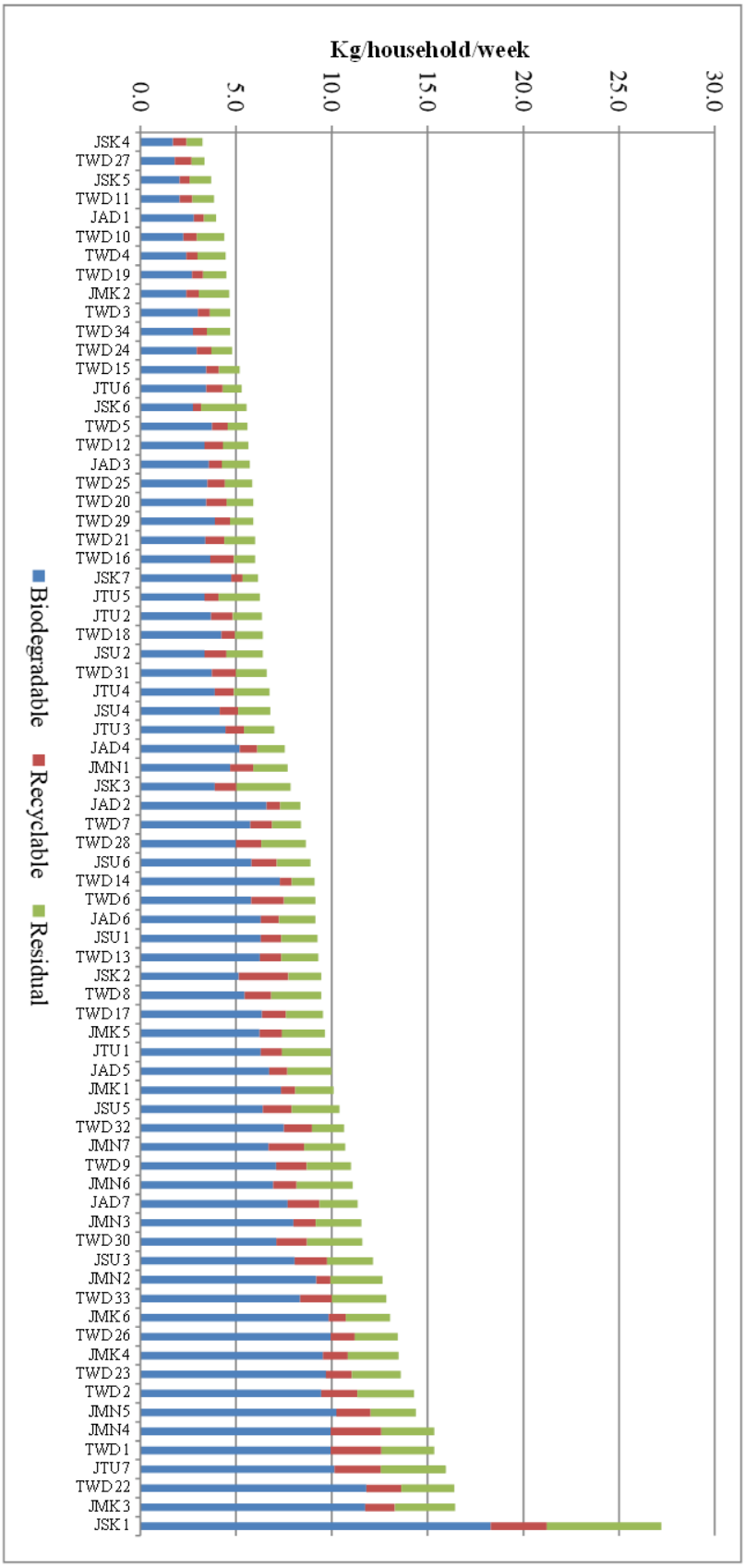

Figure 6 Composition for each household sampled based on biodegradable, recyclable and residual waste components

4. Discussion

4.1. Composition

4.1.1. Food waste

The waste composition study indicated that 29.2% of the waste is made up of food waste consisting mainly of vegetable, fruits and other scraps resulting from food preparation. The result differs from household waste characterization studies carried out in other Nigerian cities by Abur et al. (2014), Bichi & Amatobi (2013), and Igbinomwanhia et al. (2014). Abur et al. (2014) in their study of Abuja discovered that 52.0% and 56.2% of waste generated was food during the dry and rainy season respectively. Bichi & Amatobi (2013) putting food waste at 57.5% in Kano with Igbinomwanhia et al. (2014) reported 51.3% to be food waste in Amassoma in Niger Delta. Although the percentage of food waste reported in this study falls below that of other cities in Nigeria, it clearly shows that food waste constitutes the highest percentage of the Jos waste stream. The total biodegradable waste was 65.2% - it could be that there were methodological differences in this study with those cited above, and that they included other biodegradable wastes within their food waste category. Moreover, as mentioned in Nigeria many households have businesses that operate from home, and it could be that these other studies had higher levels of food-based businesses operating from home compared to the study area. There is variation in other studies on the reported biodegradable waste level in Nigeria range from 50% to 90% of the total waste (Cointreau, 1982; Nabegu, 2013; Ogwueleka, 2009; Otti, 2011) – therefore, the findings from this study falls within these levels.

4.1.2. Ash/unburnt wood

Ash/unburnt wood constituted the second largest component in the waste stream at 18.4%. Participating households were asked to bag up their ash thereby making it easier to analyse and not contaminate the other waste sampled. The levels were similar to the findings of Nabegu (2010) who stated ash/dirt made up 22.5% of the waste stream in Kano. However, it is difficult to compare the level of ash and unburnt wood with other studies because it is often grouped together with other categories. For example, Abur (2014) observed that 25.6% of waste from Abuja was made up of 'other' forms of waste among including ash and unburnt wood. Similarly, an analysis of household waste by Amori et al. (2013) from junior staff quarters in selected tertiary institutions in Nigeria show that 14% of the waste stream was made up of other wastes including ash and unburnt wood.

The high level of ash and unburnt wood at 18.4% was mainly due to low-income households being unable to afford cooking fuel such as kerosene and gas, so they use firewood and charcoal to cook with. In addition, ash is dense and tends to dominate the weight of the waste stream.

4.1.3. Plastics

Plastics constitute 16.3% of the total waste stream from households, comprising of plastic films/bags (flexible plastic) (13.6%) and dense plastic (2.7%). The results compared closely with studies carried out by Oyelola & Babatunde (2008) at 11.32%, Amori et al. (2013) at 13.0% (bags only), Bichi & Amatobi (2013) at 17.6% in Sabongari, Kano, and Obateru (2016) 20.0% for Nigeria.

Plastics were seen littered everywhere in the study area especially plastic bags (Figure 6). Plastics are displacing traditional materials used in everyday life. For example, in the past people would collect banana leaves to prepare moi-moi. They would use the leaves to wrap food for steaming, however for convenience people are now using plastic films which is to the detriment of the environment because plastics are non- biodegradable.

Dense plastic included water bottles, jerry cans, plastic buckets and plastic plates. These were however few in quantity because observation showed that they were highly being reused by households.

Figure 6 Examples of plastics littering the study area

4.2. Other materials

Materials such as electrical and electronic waste, glass, and metals made up 3.7%, 3.6%, and 3.2% of the waste respectively – there is an established informal infrastructure in place to reuse and recycle these waste materials in Jos.

4.2.1. Solid waste generation rates

Achi et al. (2012) used a questionnaire to derive the waste generation rate for Abeokuta. Achi et al. stated it was however difficult to conclude an accurate value because 58.1% of the respondents could not estimate their solid waste generation rate, therefore an estimated value of 0.60 kg/cap/day was assumed. The approach adopted in this study of collecting weight data and information on household size overcame the challenge encountered by Achi et al. (2012), thereby generating a more reliable data.

The average household size from those sampled was 6.3 and the generation rate was 0.47 kg/capita/day. This is in line with World Bank data for Less Economically developed Countries (LEDCs) which is between 0.30 to 0.60 kg/capita/day (Hoornweg and Bhada-Tata, 2012). Similarly, it is comparable with other studies undertaken in Nigeria: Sha'ato (2007) obtained 0.48kg/capita/day for Makurdi, Bichi and Amatobi (2013) found 0.31 kg/capita/day for Kano, while Solomon (2009) had presented 0.49 kg/capita/day for average Nigerian communities with households and commercial centres.

4.2.2. Factors affecting solid waste generation in households

Kayode & Omole, (2012) lists factors that could affect the characteristics and composition of waste from households, other examples include Afroz et al. (2010), Grover & Singh (2014), and Sivakumar & Sugirtharan (2010). Nnaji (2015) cited factors such as time of the year, economic status, population density, lifestyle/habits, coverage of the study in terms of time and space and seasonality (rainy or dry season). The research method applied in the study helped to identify some of these factors influencing waste generation rates.

4.2.3. Household Size

Household size refers to the total number of people living in a household – this was captured from questionnaires. The average household size was found to be 6.3 this compares with the average household size in Nigeria at 4.6 (Nigerian Demographic and Health Survey, NDHS), 2013) while that of Jos Bukuru Metropolis was 5.5 (Knoema, 2016). This shows that the average household size for the low-income areas in Jos is higher than the national average and that of greater

Jos city. As set out in Table 3, the household size varied from 1 to 15 while the median was 6.3. It also shows the difference in the per capita waste generation rate against household size in the study area. There seems to be no direct relationship between household size and the average per capita waste generation rate, and the low sample size is noted. Ogwueleka's (2013) survey of household waste composition and quantities in Abuja revealed no statistically significant difference between household size and daily per capita household waste generation in low-income group.

It is important to note that majority of the households claimed that their household size was not stable, as family members come and go back to school, and relations and friends also come for holidays either from the village or other parts of the country. The typical make up of households in the study area is complex and it is usual to find grandparents, grown up children and other relations making up extended family households, with only a few nuclear families.

Table 3 Household size and mean waste generation per capita per day

Household size	Number of households	Average per capita generation rate (kg/capita/day)
3	6	0.45
4	7	0.47
5	15	0.48
6	14	0.48
7	13	0.45
8	10	0.48
9	5	0.52
10	3	0.34
15	1	0.60

4.2.4. Income

The minimum wage in Nigeria is currently NGN18, 900 (£47.54) per month and households that earn less than NGN50, 000 (£135.50) are classified as low-income households (EFInA, 2011). Responses from the questionnaire show that only 43.2% of households sampled had an income of less than NGN50, 000 per month with 56.8% having middle to high income. The results show that the demographics of low-income areas are complex and that they are low to middle- and high-income earners. Table 4 shows income and average waste generation, plot of relationship between waste generation per capita and the household income.

In this study there is a relationship between the quantities of solid waste generated and level of income of the households. Figure 9 shows that households with the highest income of more than NGN150, 000 per month had the highest per capita daily waste generated at 0.7 kg, compared to 0.31 kg for households on less than NGN18, 000. It can be observed that there is a consistent increase in the per capita waste generated with increasing income. Ogwueleka (2013) associated the consumption pattern of households to increases in income resulting in changes to the composition and quantities of household waste generated. In a survey of household waste composition and quantities in Abuja, Ogwuleka (2013) discovered that even a slight increase of income caused eating patterns of people to change.

This study is in agreement with Hoornweg & Bhada Tata (2012), Ogwueleka (2009), and Sivakumar & Sugirtharan (2010) that the quantity of solid waste generation depends on the income level of households, which applies to both LEDCs and MEDCs (Visvanathan & Trankler, 2006) including high- and low-income households (Sujjaudin et al, 2008). The implication of income on consumption is that as the economic situation of households improves their living standard goes up, changing consumption patterns leading to increased waste generation. In the same manner the increase of waste is associated with growth of GDP per capita (Shan, 2010).

Table 4 Income and mean waste generation

Householdmonthly income (NGN)	**Number of households**	**Average waste generation rate (kg/cap/day)**	**Categorybased on EFInA (2011)**
< 18,000	15	0.31	Low income (43.2%)
18,000 – 50,000	17	0.45	
50,000 - 100,000	26	0.49	Middle/high income (56.8%)
100,000 – 150,000	11	0.56	
>150,000	5	0.70	

4.2.5. Lifestyle related activities

Lifestyle in the context of this research refers to how citizens live their everyday life; their actions can influence waste generation levels. Some of the lifestyle characteristics which were observed during this research include daily cleaning, economic activities within households, recovery of materials, and cooking and eating habits.

Waste resulting from business activities taking place at households could contribute in increasing the quantity of waste produced from households. Some households were observed to carry out business activities from home as their main source of income. Examples included food vendors (mama put) when food is prepared from home before being taken to be sold in public places. As well as influencing food waste levels, associated waste such as ash could be increased from escalated cooking activity. Two households (JSU7 and TWD23) were observed to be food vendors who prepared most of their foods at home. JSU7 generated 5.45 kg/week food waste and 4.40 kg/week ash/ unburnt wood, while TWD23 generated 6.30 kg/week food waste and 3.15 kg/week ash/unburnt wood – this compares to median values for of the sample of 2.05 kg and 1.65 kg for food and ash respectively.

Corn millers had milling machines in their yards where customers come with their corn to mill and leave the chaff with the millers. JMN3 ran a corn milling enterprise, the food waste generated from their home was 7.05 kg/week, most of all households sampled. Other home-based business activities included having small shops, tailoring, hair-dressing, selling fire wood or charcoal, roasting yam, dodo or maize, shoe repairs, selling fruits and vegetables, and keeping poultry at homes. Further research needs to be carried out on households that conduct these businesses in order to determine the impact of these economic activities on waste levels.

The use of firewood and charcoal as a cooking fuel was observed within households therefore ash/unburnt wood made up 14.3% of the waste stream. It is also a common practice in low-income areas to see people using plastics, paper or grass to ignite fires.

Domestic food making and consumption patterns would also impact on the levels of waste. Observations indicated that some households cook once a day in the evening. In such households, members usually leave home in the morning and buy either ‘akara’, ‘masa’, ‘akamu’, ‘moinmoin’ or ‘chinchin’ from food vendors or hawkers for their breakfast and eat on their way. They also use ‘mama put’ or food vendors for their lunch at their workplace, market, office or school. This would reduce the quantity of waste generated in their homes. Direct observations revealed that the high quantity of food waste was as a result of consuming unprocessed foods such as yam, potatoes, vegetables and fruits, while the low content of metal waste materials was the result of not eating canned foods or selling metals to the informal workers.

In the study area household members were seen sweeping their houses, yards and surroundings in the morning – this is typical in Nigeria. This could have an effect on the waste characteristics, as all wastes resulting from the cleaning process would enter the residual waste stream. Some yards and houses had soil floors and this would impact the levels of fines present.

5. Conclusion

The main findings from the waste composition study show that the waste generated from the study areas were made up of biodegradables, recyclables, and residuals. The waste materials that are of priority for are the biodegradables which could potentially be composted and used as organic fertilizer. These materials consist of food waste, ash/ unburnt

wood, fines, paper, textile and garden waste. Those which can be reused or recycled are dense plastic, electrical and electronic waste, glass, and metals. Solid wastes are generated from households. Households with the highest income generate the greater number of solid wastes.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this research work.

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