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Household Plastic Waste Generation and Composition in Selected Locations Within Kaduna Metropolis

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Abstract

Indiscriminate disposal of plastic waste is an emerging environmental and economic problem within Africa and other continents of the world. The aim of the research is to assess the "generation, composition and the seasonal variation of household plastic waste generated in Kaduna metropolis". Applying a stratified sampling method, the plastic waste was collected from 100 households within the metropolis and classified into seven (7) types of plastics introduced by the Society of Plastic Industry. The plastic waste was sorted into various groups using their Resin Identification code (RIC) and Katz (1998) method of identification of polymers for the noncoded plastics. A total of 6052.45 Kg of Household plastic waste generated by 1516 residents from 100 household was collected and analysed. A mean per capita generation of 0.067kg/cap/day was calculated for the entire study area with an estimated annual generation rate of 53,601.95 tonnes/year. A significant variation in waste generation was observed between the two seasons ($p < 0.05$) with the Dry-season having a mean per capita generation of 0.060 kg/cap/day and 0.067 kg/cap/day for Wet seasons. Household plastic waste stream in Kaduna metropolis comprise of PET (15.73%), HDPE (10.47%), PVC (1.26%), LDPE (27.51%), PP (8.95%), PS (8.93%) and Others plastics (27.15%). The average bulk density of household plastic waste in Kaduna metropolis was 69.24 kg/m^3 which varies significantly ($p < 0.05$) between the seasons with a mean bulk density of 67.83 kg/m^3 in dry season and 70.65 kg/m^3 in wet season. The mean Moisture content of generated household plastic waste in Kaduna Metropolis was 10.38% which varies significantly ($p < 0.05$) between the seasons with a mean moisture content of 8.83% in dry season and 11.93% in wet season.

Keywords: Plastic waste; Per capita generation; Seasonal variation; Waste composition

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1. Introduction

The large amount of plastic waste being generated is part of the major environmental conundrums of our time. Both, the production of this material and the incorrect waste management cause several environmental problems. It is estimated that 80% of the waste present in our seas today are plastics which come from land (Mónica *et al*., 2018). These plastics constituted about 10% of our household waste, most of which are being discarded in landfill (Barnes, 2009; Hopewell *et al.*, 2009).

Plastic waste generation and accumulation in the environment is an issue of great concern and the factors behind the waste accumulation is still looking set to continue. Even though lately, a little reduction has been noticed in plastic production, the decline is unlikely to be maintained. Due to the usefulness of plastic materials, there is a high tendency for an increase in its application which will lead to an increase in more plastic products to meet up the demand of the consumers. The rise in use and manufacture of plastic in advanced and developing countries is an issue of special concern, as the complexity of their waste management structure may not be evolving at a faster rate enough to handle their ever-growing plastic waste creation (European Commission, 2011).

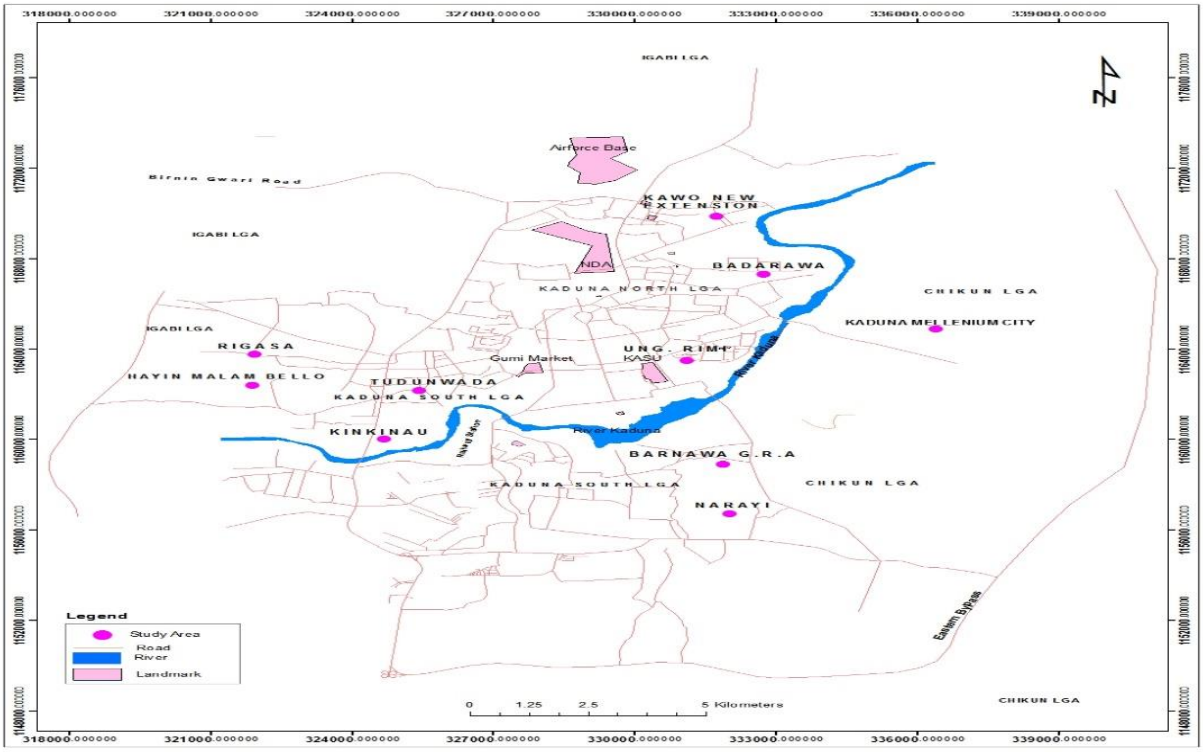
Plastic waste is produced from different sources and quantity of the waste generated depends on the consumption pattern, level of development and financial status of the place (Pan *et al.*, 2015).

A waste detailed quantification and characterization is necessary for integrated solid waste management strategies to be successful (Sakai *et al*., 1996; Oyelola and Babatunde, 2008). And such information also determines the feasibility of the installation of waste recycling and energy recovery plants (Zeng et al. 2005; Gidarakos et al. 2006; Chang and Dávila, 2008).

Material and Method

Study Area

The study was conducted in Kaduna metropolis. Kaduna metropolis is the capital of Kaduna State (Fig.3.2). It is located between latitudes 10^{o} 22’00’’-10^{o} 40’00’’ N and longitudes 7^{o} 20’00’’-7^{o} 028’00’’ E (Adewuyi, 2008). The Metropolis is made up of four Local Government Areas: Kaduna North, Kaduna South, Igabi and Chikun Local Government. The four LGAs that made-up the metropolis has a population of 2,389,984 persons as of 2020 projection by Kaduna State University, GIS unit (KASU-GIS, 2020).



A Map Showing the Study Area.

Collection of Plastic Waste Sample

Due to the heterogeneity of the study area, a Stratified Random Sampling (SRS) technique was employed to choose areas for collection of samples. The stratification was based on population density of the locations. The four LGAs that constitute the metropolis were stratified into 3 distinct groups; High-Density area (HDA), Medium-Density Area (MDA) and low-Density Area (LDA). The study was carried out in 10 randomly selected areas representing each of the strata; Badarawa, Tudun wada, Rigasa and Narayi (HDA), Kawo new extention, Kinkinau, Hayin Malam-Bello and Kaduna millennium city (MDA), U/rimi GRA, Barnawa GRA (LDA).

The plastic wastes were collected from hundred (100) randomly selected households, ten (10) houses from each of the study areas. Each household was provided with a refuse bag and identified with the sample location and family size. Generated solid waste for 7days (one week) was collected once a month for the period of the research.

The sampling was conducted once in every month all through the Wet and dry season of 2020 (i.e. January to December of year 2020 with the exception of April and May due to the covid-19 lockdown).

The collected waste was transported to the research facility where the plastic waste components are sorted and weighed with a weighing balance.

Plastic Waste Characterization

The collected plastic waste samples were reduced to a manageable sample size for the characterization analysis using the Cone and Quartering Technique as described by EPA Municipal Solid Waste Characterization Procedures (1996). The plastic waste components were classified into seven (7) categories according to the Resin Identification Code (RIC) system designed for material recycling and recovery by the Society of the Plastics Industry: (1) Polyethylene terephthalate (2) High-density polyethylene (3) Polyvinyl chloride (4) Low-density polyethylene (5) Polypropylene (6) Polystyrene (7) Other plastics. The plastic waste sample was spread on the sorting platform and sorted physically into the various categories of plastics using their trademark or SPI code (A triangle of arrows with a number 1 to 7 inside indicating the kind of plastic the material is made up) that is mostly imprinted on the bottom of the plastic materials. The remaining noncoded plastics are identify and classified in accordance with Katz, (1998) "Identification of Polymer".

Bulk Density Determination

The bulk density of the sample was measured, using the procedure described in EPA Municipal Solid Waste Characterization Procedures (1996). Using a container of known volume (120litres) and weight.

Determination of Moisture Associated with the Plastic Waste

The Moisture or water associated with the Plastic solid wastes was determined in a homogenized sample in accordance with the procedure of Baba *et.al.* (2014). Using 1kg representative sample dried under the sun for 6 hours and oven dried in a drying oven at 105^{o}C until a constant weight is recorded.

Statistical Analysis

For the analysis of Data obtained from this research;

A simple descriptive statistic; Mean (x), Standard deviation (S.D), Coefficient of Variation (C.V), chart and Percentages (%) were used to summarize the data in Tabular form and charts for easy analysis and interpretation. A one-way analysis of variance was used to establish the variations ($P<0.05$); Spatial variation on the waste generation between the study areas. A paired sample T-test was used to test the seasonal variations in Plastic waste generation rate, Bulk density and Moisture content. All statistical tests were conducted using XRealStats Package version 7.8 for excel 2016.

Results and Discussion

Plastic Waste Generation Rate: The obtained mean weekly household plastic waste generated from different municipalities in Kaduna metropolis, during the period of January to December of 2020 is shown in table 4.1. A total of 6160.45Kg of Household plastic waste generated by 1516 residents was collected from different population densities in the metropolis (Kaduna Metropolis) over the period of the research. The mean per capita Household plastic waste generated in the Metropolis was calculated to be 0.064 Kg/cap/day which ranges from 0.050–0.104 kg/cap/day depending on the location. This figure falls within the estimated average per capita plastic waste of Nigeria that ranges from 0.02 kg/cap/day (7.5 kg/cap/year) up to 0.12 kg/cap/day (45 kg/cap/year) in populated cities like Lagos (Plastic Atlas, 2020). A lower per capita household plastic waste generation of 0.02kg/cap/day (17.8 g/cap/day) was recorded for Can Tho City in Vietnam (Thanh *et.al.,* 2011), and 0.036 kg/cap/day for Pakistan, and 0.04 kg/cap/day for china (Law *et.al.,* 2020). While a higher per capita of 0.29, 0.27, 0.22 and 0.11 kg/cap/day was reported for advance countries like United State, United-kingdom, Germany and Spain respectively (Law *et.al.,* 2020).

A One-way Analysis of Variance performed to determine the spatial variation on the weekly waste generation within the study areas indicate a highly significant variation in the amount of waste generated by the different municipalities studied (F (9,90) = 96.95, $p < .001$). The highest per capita waste generation was observed in the Low-density localities. These low-density localities referred to as Government Reserve Areas (GRAs) are majorly inhabited by high earning individuals (Akinwumi, 2014). Therefore, the high per capita generation can be attributed to the high income of such locality's residents. Ogwueleka (2009) work and a Forbes, (2020) report indicates people in richer societies or high-income earners generate more plastic waste.

Table 2 shows the Estimated Annual Plastic waste Generated in Kaduna metropolis. The Estimated Annual Plastic waste Generated was estimated using the established mean per capita generation of metropolis and the population of Kaduna Metropolis (2,389,984) as estimated by Kaduna State University GIS Unit (KASU-GIS, 2020). Considering the 2020 projected population, an estimated total of 53601.95 tonnes/year of household plastic waste was generated in Kaduna metropolis, with Kaduna North, Kaduna South, Igabi and Chikun LGA generating 15219.25, 14922.1, 12685.96, 10774.64 tonnes/year respectively.

Table 1. Mean Weekly Household Plastic Waste Generation in LGA's of Kaduna Metropolis

LGA	Population Densities	Number of Households	No. of Persons	Mean weekly waste generated (Kg)	Daily Per Cap. Generation (Kg/Cap/day)	LGA Mean Per capita generation
KDNRH	H.D	10	213	73.88	0.050	
	M.D	10	117	59.10	0.072	0.075
	L.D	10	65	47.19	0.104	
KDSRH	H.D	10	215	78.87	0.052	
	M.D	10	127	55.97	0.063	0.067
	L.D	10	84	49.82	0.085	
IGABI	H.D	10	247	82.96	0.048	0.053
	M.D	10	127	51.61	0.058	
CHIKUN	H.D	10	205	72.91	0.051	0.052
	M.D	10	117	43.73	0.053	
Total		100	1517			
Mean						0.062

Table 2. The Estimated Annual Plastic Waste Generation of Kaduna Metropolis

LGA's	Per Capita Waste Generation (kg/cap/day) *	Population**	Tons/dy	Tons/yr
KDNRTH	0.075	554869	41.70	15219.25
KDSTH	0.067	612941	40.88	14922.10
IGABI	0.053	655590	34.76	12685.96
CHIKUN	0.052	566584	29.52	10774.64
Total		2389984	146.85	53601.95

*__Source__: Kaduna State University, GIS unit **__Source__: This current field study.

Seasonal Plastic Waste Generation: The Seasonal Household Plastic Waste generation for Kaduna Metropolis (Table 3.) shows a mean per capita generation of 0.060 kg/cap/day (S.D = 0.016), while in wet season, the mean per capita plastic waste generation was 0.067 kg/cap/day (S.D = 0.021). The coefficient of variation for the mean per capita generation was 26.63% in the dry season and 31.52% in wet season. The coefficient of variation for the two seasons was a little close indicating a slight variation in the per capita generation of the municipalities.

A Paired two sample t-test for means confirmed the variation between the means of the two seasons confirmed, there is a significant variation between the per capita waste generation in wet season and dry seasons in Kaduna Metropolis, ($t(20) = 2.262$, $p = 0.043$). The significant difference may result from the differences in the plastic waste generation rate and moisture content of the waste between the two seasons.

Table 3. The Mean Seasonal Household Plastic Waste Generation in Kaduna Metropolis.

LGAs	Population Densities	No. of Residents	Weekly mean Waste for Dry Season (kg/wk)	Per Capita Waste Generation (kg/cap/day)	Weekly mean Waste for Wet Season (kg/wk)	Per Capita Waste Generation (Kg/Cap/day)	Test Statistics and P-value
KDNRTH	H.D	213	73.06	0.049	74.70	0.050	
	M.D	117	57.96	0.071	60.25	0.074	
	L.D	65	41.36	0.091	53.02	0.117	
KDSTH	H.D	215	77.19	0.051	80.55	0.054	
	M.D	127	52.46	0.059	59.49	0.067	
	L.D	84	49.75	0.085	49.89	0.085	
IGABI	H.D	247	83.87	0.049	82.05	0.047	
	M.D	127	47.80	0.054	55.41	0.062	
CHIKUN	H.D	205	72.68	0.051	73.13	0.051	
	M.D	117	37.58	0.046	49.88	0.061	
Mean				0.060		0.067	

T-t = *2.262, P = 0.043*

Keys: H.D – High Density, M.D – Medium Density, L.D – Low Density

Waste Composition: The composition analysis (Figure 2.) indicates that most of the plastic waste generated in Kaduna metropolis is made up of LDPE (27.51%). Others plastics (i.e. plastics not defined by the SPI code or a mixture of two or more plastics) are the second most generated (27.15%) followed by PET (15.73%), HDPE (10.47%), PP (8.95%), PS (8.93%), and PVC (1.26%) having the least prevalence in the plastic waste stream.

The percentage composition of the LDPE obtained in Kaduna Metropolis closely agrees with the 23% quoted by Olusunmade *et al.* (2019), higher than the 17.4% reported by Areeprasert *et al.,* (2017) in Bangkok Thailand and it is lower than (55%) reported by Gwada *et al.* (2019) in Watamu, Kenya. The high percentage of LDPE in the metropolis household plastic waste can be attributed to the high consumption of sachet water and the use of single-use polyethylene groceries' bag.

PET being one of most common plastic litter in our gutters and streets is having the third highest composition (16%) which appears to be higher than the 10% quoted by Olusunmade *et al.,* (2019).

PVC shows the least prominence in the plastic waste stream of Kaduna metropolis with a value of 1%. It also shows the least composition in the work of Czajczynska *et al.* (2017), Areeprasert *et al.* (2017), Olusunmade *et al.* (2019) and Gwada *et.al.* (2019).

Five of the most imported plastic resins (LDPE, HDPE, PP, PET and PVC) into Nigeria (Varrella, 2020), constituted about 64% of the identified household plastic waste of Kaduna metropolis. Recycling these wastes will save the country a huge amount from it import and eradicate 64% of the country's household Plastic waste.

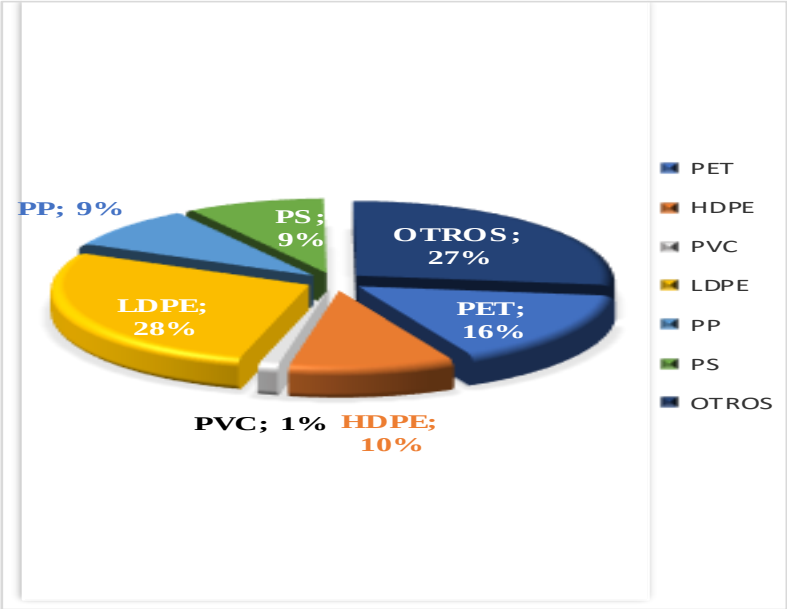


Figure 2. A Pie Chart Showing the Mean Percentage Composition of Household Plastic Waste Generated in Kaduna Metropolis.

Bulk density: The bulk density is an important parameter for an efficient waste management. It plays a significant role in determining the method of waste collection, equipment to be provided or use, its storage and transport.

The average bulk density of household plastic waste obtained by this study for Kaduna metropolis was 68.60 kg/m^3 (Table 4.). The value for the bulk density of the HHPW obtained falls between 56 kg/m^3 and 60 kg/m^3 reported in the work of Alabdraba and AL-Qaraghully (2013) and Foday *et al.* (2017), and 79 kg/m^3 reported by Bowan and Tierobaar (2014).

A significant difference (*t(20) = 2.262 , p = 0.045*) was observed in the mean bulk densities of the household plastic wastes between the two seasons (67.83 kg/m^3 in dry season and 70.65 kg/m^3 in wet season). The bulk density of waste relies on moisture content, composition and distribution of the waste (Foday *et al.*, 2017). Therefore, the variation in bulk densities between the seasons can be attributed to the observed differences in moisture content of the household plastic waste between the seasons.

Table 4. Bulk Density of the Household Plastic waste generated in Kaduna Metropolis

LGAs	Population Densities	Bulk density in Dry season (kg/m^3)	Bulk Density in Wet Season (kg/m^3)	Mean Bulk Density (kg/m^3)	Test Statistics and P-value
KDNRTH	H.D	72.69	75.24	73.96	
	M.D	66.12	69.07	67.59	
	L.D	58.11	68.10	63.10	
KDSRTH	H.D	74.33	72.22	73.27	
	M.D	64.73	71.08	67.91	
	L.D	64.45	65.48	64.96	
IGABI	H.D	73.27	73.52	73.40	
	M.D	68.04	72.77	70.40	
CHIKUN	H.D	74.62	72.26	73.44	
	M.D	61.92	66.81	64.37	
Mean		67.83	70.65	**69.24**	

T-test =*2.262, P = 0.045*

Moisture content: The moisture content of waste is an important factor to consider for an effective waste management. The moisture content plays a significant role in choosing the right method for the management of municipal solid waste.

The mean moisture content of generated household plastic waste in Kaduna Metropolis (Table 5), was 10.38%, which was close to 14.89% reported for Numan Town North-Eastern Nigeria (Abubakar *et al.*, 2018) and higher than what was reported for plastic waste in Taman University, Malaysia (Foday *et al.*, 2017). The moisture in the waste is higher in the developing than developed countries (Ogwueleka, 2009).

A significant variation in moisture content ($t(20) = 2.262$, $p < .001$) exists between the seasons ranging from 8.83% - 11.93% from dry to wet season. Seasonal change in moisture content of the plastic waste in

the wet season can necessitate an addition of extra fuel to maintain a suitable combustion. (Ogwueleka, 2009; Ozcan *et al.*, 2016).

Table 5. Moisture Content of Household Plastic Waste generated in Kaduna Metropolis

LGA	Population Densities	Moisture Content in Dry Season (%)	Moisture Content in Wet Season (%)	Mean moisture Content (%)	Test Statistics and P-value
KDNRTH	H.D	9.05	12.26	10.65	
	M.D	8.83	11.44	10.13	
	L.D	8.26	10.18	9.22	
KDSRTH	H.D	9.28	12.54	10.91	
	M.D	8.92	12.02	10.47	
	L.D	8.24	11.23	9.73	
IGABI	H.D	9.13	12.62	10.87	
	M.D	8.83	12.11	10.47	
C	H.D	9.04	12.60	10.82	
HIKUN	M.D	8.70	12.29	10.49	
Mean		8.83	11.93	10.38	

T-test =*2.262, P <0.001*

2. Conclusion

The situation of household plastic waste in Kaduna Metropolis; its generation and composition have been assessed in this study. HHPW generated in Kaduna Metropolis from the period of January to December 2020 have amount to 53601.95 tonnes/year at an average per capita of 0.064 kg/cap/day, ranging from 0.050-0.104kg/cap/day in the high-density areas to the low-density areas.

The study indicates that LDPE (27.51%) is the main component of the household plastic waste stream of Kaduna metropolis followed by PET (15.73%), HDPE (10.47%), PP (8.95%), PS (8.93%), and PVC (1.26%). Others plastics (i.e. plastics not defined by the SPI code or a mixture of two or more plastics) constituted 27.15% of the household plastic waste stream.

It was concluded that a seasonal variation in waste generation exists between the two seasons with wet-season having the highest mean per capita generation of 0.067 kg/cap/day as against 0.060 kg/cap/day in

the dry-season. Moisture content of the household plastic waste which is higher in the wet season (11.93%) than in dry Season (8.83%) has also varied significantly across the seasons and is among the factors that contribute to the seasonal difference in the per capita waste generation of the Metropolis.

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