JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(1), MARCH, 2025
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

Effect of Seasons and Income Level on Solid Waste Generation Rates and Composition: A Case Study of Kaduna and Bauchi, Nigeria

[1]Rabia Lawal Batagarawa, [2]Dalhatu Saleh, [1]John Engbonye Sani, [3]Abbas Ibrahim Muazu, [1]Saminu Ahmad[5]
[1]*Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria*
[2]*Department of Civil Engineering Nigerian Army University Biu, Nigeria*
[3]*Department of Architecture Base University Abuja*

ABSTRACT

Solid waste management in urban areas of developing nations, such as Nigeria, poses significant social and environmental challenges. While research has addressed some obstacles to sustainable waste management, the impact of seasonal variations and income levels on waste generation and composition remains underexplored in these regions. This research study investigated the effect of level of income and seasons on the solid waste generation rates and composition in Kaduna and Bauchi, Nigeria. Random stratified sampling and questionnaire survey were used to identify the income levels of the households, solid waste was collected from the households and generations rate and composition were determined within both dry and wet season. The waste generation rates in Kaduna and Bauchi were found to be 0.44kg/capita/day and 0.32kg/capita/day in wet season and 0.35kg/capita/day and 0.25kg/capita/day in dry season respectively, also the generation rates in Kaduna according income level grouped into high, middle and low income was found to be (0.59, 0.42, 0.33) kg/capita/day and (0.48, 0.34, 0.24)kg/capita/day in wet and dry season respectively and that of Bauchi {(0.35, 0.24, 0.17)kg/capita/day and (0.43, 0.31, 0.22)kg/capita/day in dry and wet season respectively. The solid waste composition in Kaduna was found to be 53.5% food waste, 18.24% plastics, 2.02% green waste, 2.14% paper, 4.48% textile, 0.64% metals, 0.62% glass/ceramics, and 18.41% other waste in dry season and 53% food waste, 3.2% green waste, 2.2% paper, 9.3% textile, 23.2% plastics, 0.66% metals, 0.52% glass/ceramics, and 8.3% other waste in wet season. Also waste composition in Bauchi was found to be 47.1% food waste, 2.5% green waste, 3.3% paper, 7.7% textile, 16.5% plastics, 0.9% metals, 1% glass/ceramics, and 21% other waste in dry season and 43.4% food waste, 3.4% green waste, 7.56% paper, 5.9% textile, 16.8% plastics, 3.7% metals, 2.96% glass/ceramics, and 16.3% other waste in wet season. The overall results show that income level and season has effect on the solid waste generation rate and composition with higher waste generation in high income groups and ascends to low income groups, also high in wet season than in dry season. Seasonal variation seems to have minimal effect on the composition with slight increase in recyclables in wet season. Therefore, this research study has provided valuable insights for improved waste management strategies. ANOVA results show that income levels affect waste generation in both Kaduna and Bauchi across seasons. T-test results

ARTICLE INFO
Article History
Received: August, 2024
Received in revised form: November, 2024
Accepted: February, 2025
Published online: March, 2025

KEYWORDS
Solid Waste, Generation Rate, Composition, Income Level, Seasons

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

indicate significant seasonal impacts on waste generation rates, with higher rates in the wet season. Multiple regression analysis reveals that the dry season regression equation is the best model for predicting waste generation in both states.

INTRODUCTION

Solid waste management in urban areas of developing nations such as Nigeria pose a significant social and environmental burden. Although there has been research into clearing the obstacles hindering the adoption of sustainable management approaches, understanding the influence of seasonal variations and income levels on waste generation, composition, and disposal practices remains largely unexplored in these regions.

Solid waste generation rate serves as a fundamental metric for assessing the volume of waste generated by a community, region, or country, providing insights into consumption patterns, economic activities, and environmental impacts (Iacovidou *et al.* 2017). Solid waste generation is a multifaceted issue with far-reaching implications for public health, environmental quality, and resource management (Sikder *et al.* 2024). By examining the factors influencing waste generation rates and patterns, policymakers, researchers, and waste management professionals can develop informed strategies to address the challenges posed by increasing volumes of waste (Masebinu *et al.* 2017; Khan *et al.* 2016). This study will examine income level and seasonal variation as two of the factors that affect solid waste generation and composition.

The relationship between income level and solid waste generation and composition is a complex phenomenon that reflects the interplay of socioeconomic factors, consumption patterns, and waste management practices within a society (Zia *et al.* 2017). The consumption pattern of household is directly linked to the increase in income which results in changed composition and quantities of household waste (Corona *et al.* 2019). As economies develop and incomes rise, there tends to be a corresponding increase in the quantity and diversity of goods consumed, leading to higher levels of waste generation (Zia *et al.* 2017). Affluent economies often purchase more manufactured goods, and their waste contains more recyclable materials than that of low-income areas (Liu *et al.* 2019). Therefore, daily waste generation rates are often higher in high income than in lower socioeconomic groups (Ogwueleka, 2013).

Afon and Okewole (2007) examined solid waste generation in Oyo, Nigeria. They discovered a per capita waste generation rate of 0.129kg. Additionally, their regression analysis revealed a robust correlation (88%) between waste generation rate and factors such as income level, social status, and occupation. In a similar finding by Oluwole, (2015) on the determinants of municipal solid waste generation rates in 16 local government areas of Lagos state, the results of the statistical analysis on factors such as income level, education. age, and household size explained 54.9% of the variation in the household solid waste generation in the study area.

Adeleke *et al.* (2021) conducted an overview of factors influencing municipal solid waste generation and composition. Results showed diverse patterns in waste generation and composition across locations, times, and seasons. Where Socio-economic status particularly income level significantly influenced waste generation rates and the composition of waste streams, these effects are more pronounced in the proportion of organic waste, which was higher in low-income regions.

Also, in an investigation of waste generation and management practices in residential areas of Nigerian tertiary institutions, Amori *et al.* (2013) revealed that, the rate of solid waste generation is proportional to income level, with higher income earners producing more waste than low-income groups. Also, Ogwueleka (2013), conducted a study with the objective of assessing the quantities and composition of household solid waste generation in Abuja across various socioeconomic groups. The findings revealed an

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

average daily per capita household waste generation rate of 0.634 kg/capita/day. And the analysis of the relationship between income and daily per capita household waste generation demonstrated a positive correlation.

In a similar study conducted by Owamah *et al.* (2017) on the characterization and quantification of solid waste generation in the Ogbe-Ijoh community Delta State, Niger Delta Region of Nigeria, an estimated solid waste generation rate of 1.04 kg/person/day was found. The study also revealed positive correlations between income level and the rate of waste generation. Jadoon *et al.* (2014) has also assessed the factors affecting household solid waste generation and its composition in Gulberg Town, Lahore, Pakistan and found out that high income groups has high per capita waste generation rate (0.96kg) as opposed to middle and low income group of 0.73kg and 0.67kg respectively.

More so, Masebinu *et al.* (2017) conducted a review of factors influencing waste generation rates, focusing on the city of Johannesburg, their findings indicated that waste generation per capita is closely linked to income level. Specifically, the high-income group exhibited an average waste generation rate of 1.91 kg/capita/day, while the middle and low-income groups generated 1.01 kg/capita/day and 0.92 kg/capita/day, respectively.

Therefore, the amount of solid waste generated is closely correlated with income levels.

Nevertheless, findings from Khan *et al.* (2017) revealed that the highest waste generation rate was observed among lower-middle-income groups. This suggests that waste generation rates are influenced by various factors, including the educational level of households, in which the greater the level of education and awareness within a household regarding the adverse effects of unmanaged solid waste, the more it values the importance of effective waste management (Kayode & Omole, 2011). Other factors include; age demographics, population density, economic activities, seasonal fluctuations, waste management practices, technological advancements etc. (Senzige *et al*. 2014).

Many researchers have reported that weather conditions appear to influence both the rate of waste generation and its composition. For example, in a study by Adeniyi *et al.* (2019) on the monthly analysis of solid waste generation quantity and composition in the food vendor stalls within the market area of Obafemi Awolowo University, Ile-Ife, Nigeria, the findings revealed a notable disparity in waste production between the rainy and dry seasons. The study showed that the quantity of waste generated during the rainy months surpassed that of the dry months. August recorded the highest daily average for the year, with the highest daily per capita waste generation rate (0.21kg), whereas March exhibited the lowest daily per capita rate at 0.09kg. The study concluded that the amount of solid waste generated in the food vendor stalls of the OAU market varies with the seasonal variations throughout the year.

In a similar investigation into estimating solid waste generation in Oyo, Nigeria, Afon and Okewole (2007) observed a higher waste generation rate during October (wet season), indicating a correlation between the season and the generation rate. More so, Abel, (2007) conducted a research on the analysis on solid waste generation rates in a traditional city of Africa with Ogbomosho, Nigeria as a case study, and found that waste generation rate was higher in rainy season and early period of dry season.

Findings from sorting activities conducted at the sanitary landfill of Columbia city throughout the four seasons of 1996, indicated significant disparities among the studied seasons regarding fractions such as organic matter, paper, and metal (Zeng *et al.* 2005). Also, a rise in solid waste generation and alterations in composition was noted, particularly an increase in packaging waste, during the summer period on the island of Crete (Gidarakos *et al.* 2006). Another study investigated the characteristics of municipal solid waste composition across different seasons, represented by the months April, June, and January, in the city of Chihuahua, Mexico. Waste generation values for January (considered the low-temperature season) were 28% lower than in April (Gómez *et al.* 2009).

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Jadoon *et al.* (2014) investigated the factors influencing household solid waste generation and composition in Gulberg Town, Lahore, Pakistan. They found that the average total household solid waste generation was 0.79 kg/cap/day, with the highest rates observed during the monsoon and summer seasons (0.86 kg/cap/day and 0.77 kg/cap/day, respectively), and slightly lower rates during spring (0.75 kg/cap/day) and winter (0.76 kg/cap/day). Statistical analysis revealed a significant difference between seasons for various waste categories including food waste, cardboard, PET (Polyethylene Terephthalate), HDPE (High-Density Polyethylene), other hazardous waste, battery cells, and dust and stone. Similar result was found by (Ozcan *et al.* (2016). However, in a study conducted by Adeniyi and Afon (2022) on the seasonal quantification and characterization of solid waste generation in tertiary institutions in Nigeria, they determined that seasonal variation does not influence the composition of the waste.

Similarly, Roberts *et al.* (2010) conducted an evaluation of seasonal variation's impact on municipal solid waste composition in Abuja city, Nigeria. Their analysis of waste samples from both wet and dry seasons did not reveal significant differences in the composition of the waste. Hence depending on the location, economics activities and other factors mentioned earlier, solid waste generation rate and composition appeared to be influence by season, with some seasons experiencing higher generation rate and a composition that needs special handling. Therefore, this study aims to elucidate the influence of season and income level on waste generation and composition in Kaduna and Bauchi providing valuable insights for improved waste management strategies.

MATERIALS AND METHODS

Study Area

The effect of seasons and income level on solid waste generation rates and composition was assessed in Bauchi and Kaduna metropolis. Bauchi state is located at latitude 10° 17' and longitude 09° 49' E, with a total land area of 49,119 km^2. The population of Bauchi State in 2015 was estimated at 6,275,523, derived from the 2006 census figure of 4,653,066, indicating a growth rate of 3.6%. (Ori *et al.* 2021). Bauchi states consists of 20 local government areas of which Bauchi town is among. The major economic activities of Bauchi town are retail and whole sale trading, peasant and commercial agriculture, infrastructural investment such as hotels, construction, factories, private and government firms among others, small scale businesses and other informal trades such as street hawking.

Kaduna state is located at latitude 09° 02'N and 11° 32'N and longitude 06° 15'E and 08° 38'E with a total land area of 46,053 square kilometers. Based on the population projection for the year 2021, Kaduna State is estimated to have a population of 9.4 million individuals, constituting approximately 4.3% of Nigeria's entire population (Abdussalam, *et al.*2023). The state was ranked number four by total area of land and number three by population. Kaduna state has 23 local government areas with Kaduna city being the capital of the state and described as 8th largest city in the country as at 2006. Farming and other forms of agriculture, small and medium scale businesses are the major economic activities taking place in the city with other manufacturing and processing businesses.

Sample size and techniques

Statistical technique was used to determine the sample size at 95% confidence level with 0.05 allowable error. The sample size (n) of households selected to participate in the survey was calculated using the widely utilized equation established by Cochran (1977), which is commonly adopted by numerous researcher (Fereja & Chemeda, 2022).

Stratified random sampling as used by Fereja & Chemeda, (2022) was adopted, with the study area divided according to household income levels in both Kaduna and Bauchi. Questionnaire survey and interviews were employed to categorize the households into low (60%), middle (25%), and high-income (15%) groups. This study was conducted in two seasons (dry and rainy season)

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(1), MARCH, 2025
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

Solid waste Generation rate and composition

Daily per capita waste generation was established by measuring waste from households for 7 days across rainy and dry seasons using an equation; 1

$$waste\ generated\ per\ \frac{capita}{day} = \frac{Total\ weight\ of\ waste\ generated\ by\ each\ household}{Total\ population\ of\ the\ households}\ (\frac{\frac{kg}{capita}}{day}) \quad Eq.1$$

The composition of the waste was determined with a 50kg thoroughly mixed solid waste on approximately 24m^2 polythene sheet placed on the ground to avoid loss of moisture. The waste was sorted into food waste, green waste, plastics, textile, paper, glass, metals and other waste (Sand, fine organics, ash, and dust, Construction and demolishing waste, batteries, paints, and any other waste fraction that did not fit in other categories). Each waste fraction was weighed to determine its mass and consequently its percentage using equation 2;

$$Percentage\ of\ the\ waste\ fraction\ = \frac{weight\ of\ the\ waste\ fraction}{Total\ weight\ of\ the\ sorted\ waste} \times 100 \quad Eq.2$$

Effect of income level and season on solid waste generation rates

Statistical analysis tools such as analysis of variance (ANOVA), T- test and Multiple regression analysis were used in this study. A two-way Analysis of Variance (ANOVA), a method employed to compare means of multiple variables utilizing F-distribution. This parametric test aimed to validate the results by assessing the impact of income levels on the solid waste generation rate, by determining significance. While a t-test, a fundamental statistical method used to determine whether there is a significant difference between the means of two groups, was used to test the significant difference between the wet and dry season on the soid waste generation rates. And Multiple regression analysis was also conducted to determine the relationship between waste generation and the various income levels.

RESULTS AND DISCUSSION

A total of 3,858.62kg and 2,405.93kg of waste were collected from100 households in Kaduna and Bauchi respectively for both the dry and wet season.

Solid waste generation, income level and seasonal variation

Kaduna, solid waste generation rates were observed to vary significantly across different income groups and seasons (Table 3.10). Specifically, during the dry season, the high-income group exhibited a solid waste generation rate of 0.484 kg/capita/day, followed by the middle and low-income group with 0.34 kg/capita/day and 0.24 kg/capita/day respectively. Similarly, during the wet season, this trend persisted, with the high-income group generating the most waste at 0.59 kg/capita/day, followed by the middle-income group with 0.42 kg/capita/day, and the low-income group with 0.33 kg/capita/day.

Similar trend was observed in Bauchi (Table 3.11). During the dry season, Bauchi recorded solid waste generation rates of 0.36 kg/capita/day, 0.24 kg/capita/day, and 0.17 kg/capita/day for high, middle, and low-income groups, respectively. Similarly, during the wet season, these rates increased to 0.43 kg/capita/day, 0.31 kg/capita/day, and 0.21 kg/capita/day, respectively. This consistent pattern echoes the results observed in previous researches, indicating a direct correlation between income level and waste generation rate with high income group generating more waste (Zia *et al.* (2017); Ogwueleka, (2013); Adeleke *et al.* (2021); Amori *et al.* (2013); Owamah *et al.* (2017); Masebinu *et al.* (2017).

The observed pattern of higher waste generation among high-income groups can be

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(1), MARCH, 2025
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

attributed to their greater purchasing power and consumption habits, which often involve the acquisition of more packaged goods and disposable items. In contrast, low-income groups typically have more limited resources and may engage in practices such as recycling or reusing items to a greater extent, thus generating less waste.

Furthermore, the study also highlights the influence of seasonal variations on solid waste generation. The combined waste generation rate for Kaduna was found to be higher during the wet season compared to the dry season, with average rates of 0.44 kg/capita/day and 0.35 kg/capita/day, respectively. Also, the combined waste generation rates for Bauchi during the dry season was 0.25 kg/capita/day, while during the wet season, it increased to 0.32 kg/capita/day. This suggests a higher generation of waste during the wet season compared to the dry season, a trend consistent with the observations by aforementioned research findings (Adeniyi *et al.* (2019); Okewole (2007); Abel, (2007); Gidarakos *et al.* (2006); Jadoon *et al.* (2014).

The generation rates observed in both seasons and locations fall within the ranges typically observed for developing countries (Sharma & Jain, 2020). This indicates that while there are variations in waste generation rates influenced by factors such as income level and season, the overall patterns align with broader trends seen in similar contexts globally.

Solid waste composition and seasonal variation.

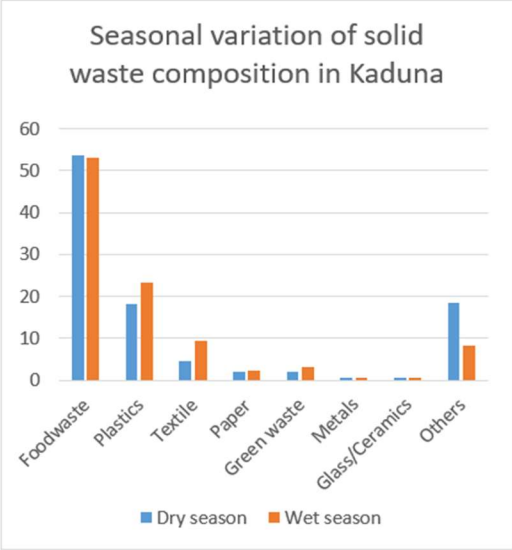

Fig. 3.1 solid waste composition of Kaduna

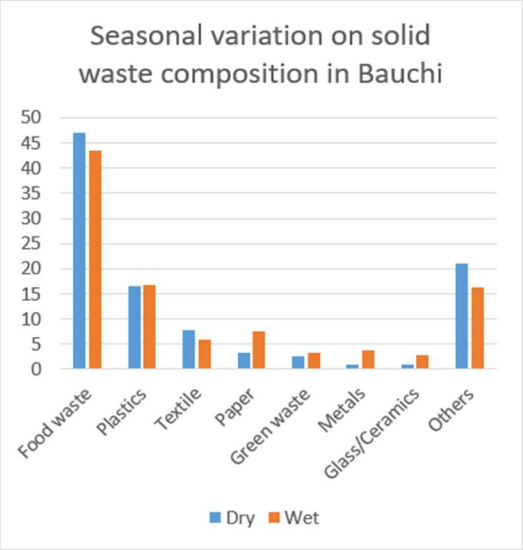

Fig. 3.2 solid waste composition of Bauchi

As seen in Figure 3.1, the waste composition of Kaduna during both the dry and wet seasons reveals distinct percentages for various categories. In the dry season, the composition consists of 53.5% food waste, 18.24% plastics, 2.02% green waste, 2.14% paper, 4.48% textile, 0.64% metals, 0.62% glass/ceramics, and 18.41% other waste. Conversely, during the wet season, the composition shifts a little to 53% food waste, 3.2% green waste, 2.2% paper, 9.3% textile, 23.2% plastics, 0.66% metals, 0.52% glass/ceramics, and 8.3% other waste.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(1), MARCH, 2025
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

Table 3.10. Average per capita solid waste generation data of Kaduna

Income Level	Season	Average per capita waste generation (kg/capita/day)														
High Income	Dry	0.43	0.52	0.59	0.53	0.61	0.81	0.36	0.32	0.43	0.23	0.56	0.32	0.56	0.52	0.47
	Wet	0.63	0.58	0.42	0.67	0.55	0.93	0.33	0.69	0.74	0.51	0.65	0.53	0.45	0.67	0.53
Middle Income	Dry	0.33	0.51	0.32	0.23	0.35	0.42	0.38	0.24	0.5	0.36	0.41	0.22	0.31	0.38	0.31
	Wet	0.46	0.63	0.15	0.3	0.66	0.36	0.31	0.39	0.69	0.21	0.52	0.56	0.54	0.56	0.28
	Dry	0.33	0.1	0.33	0.35	0.5	0.26	0.31	0.27	0.34	0.35					
	Wet	0.28	0.41	0.32	0.4	0.54	0.46	0.3	0.21	0.49	0.51					
Low Income	Dry	0.42	0.17	0.33	0.27	0.16	0.24	0.09	0.19	0.23	0.32	0.27	0.36	0.22	0.15	0.1
	Wet	0.39	0.28	0.22	0.26	0.26	0.53	0.41	0.61	0.08	0.44	0.36	0.32	0.31	0.4	0.36
	Dry	0.3	0.15	0.29	0.3	0.15	0.27	0.1	0.22	0.08	0.22	0.27	0.32	0.12	0.53	0.35
	Wet	0.36	0.19	0.31	0.38	0.31	0.13	0.26	0.46	0.61	0.61	0.43	0.28	0.2	0.35	0.23
	Dry	0.24	0.14	0.16	0.22	0.3	0.23	0.19	0.17	0.45	0.17	0.24	0.18	0.12	0.29	0.18
	Wet	0.42	0.38	0.34	0.32	0.32	0.44	0.19	0.24	0.41	0.41	0.18	0.11	0.37	0.39	0.13
	Dry	0.26	0.32	0.28	0.14	0.53	0.26	0.13	0.26	0.4	0.21	0.31	0.26	0.37	0.17	0.3
	Wet	0.13	0.69	0.32	0.28	0.49	0.1	0.11	0.7	0.3	0.43	0.36	0.28	0.35	0.12	0.27

*Average high, middle and low income in dry and wet {(0.48, 0.34, 0.24) and (0.59, 0.42, 0.33)}kg/capita/day respectively.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(1), MARCH, 2025
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

Table 3.11. Average per capita solid waste generation data of Bauchi

Income Level	Season	Average per capita waste generation (kg/capita/day)														
High Income	Dry	0.33	0.62	0.34	0.45	0.44	0.53	0.19	0.28	0.21	0.32	0.34	0.27	0.31	0.37	0.31
	Wet	0.41	0.72	0.45	0.36	0.43	0.58	0.32	0.35	0.44	0.59	0.24	0.38	0.4	0.33	0.48
Middle Income	Dry	0.31	0.29	0.23	0.31	0.18	0.19	0.31	0.18	0.3	0.26	0.23	0.18	0.31	0.18	0.21
	Wet	0.42	0.3	0.12	0.35	0.35	0.38	0.35	0.24	0.45	0.21	0.18	0.21	0.23	0.26	0.57
	Dry	0.24	0.29	0.22	0.11	0.25	0.19	0.32	0.13	0.37	0.2					
	Wet	0.43	0.26	0.17	0.34	0.46	0.25	0.29	0.4	0.25	0.31					
Low Income	Dry	0.24	0.14	0.09	0.14	0.22	0.2	0.11	0.11	0.25	0.26	0.24	0.13	0.08	0.1	0.23
	Wet	0.19	0.22	0.29	0.16	0.13	0.28	0.18	0.06	0.11	0.21	0.11	0.17	0.21	0.14	0.2
	Dry	0.23	0.14	0.12	0.17	0.24	0.15	0.14	0.1	0.05	0.08	0.12	0.2	0.14	0.19	0.28
	Wet	0.29	0.26	0.27	0.1	0.17	0.1	0.08	0.05	0.08	0.06	0.07	0.2	0.1	0.11	0.11
	Dry	0.11	0.2	0.18	0.3	0.13	0.4	0.08	0.14	0.19	0.12	0.21	0.04	0.21	0.23	0.19
	Wet	0.25	0.06	0.17	0.12	0.51	0.21	0.23	0.16	0.29	0.25	0.29	0.25	0.23	0.24	0.24
	Dry	0.35	0.15	0.07	0.12	0.24	0.15	0.36	0.39	0.17	0.16	0.15	0.17	0.17	0.09	0.12
	Wet	0.39	0.21	0.39	0.29	0.39	0.29	0.29	0.41	0.28	0.08	0.33	0.62	0.24	0.31	0.32

*Average high, middle and low income in dry and wet {(0.35, 0.24, 0.17) and (0.43, 0.31, 0.22)}kg/capita/day respectively

Notably, the fraction of food waste remains consistent across both seasons, indicating minimal variation. However, there is a notable increase in the proportion of plastics during the wet season compared to the dry season, aligning with findings from Gidarakos *et al.* (2006) in a developed country context. Additionally, there is a noticeable rise in textile composition during the wet season. A slight increase in green waste during the wet season is evident, reflecting the growth of vegetation during the rainy season. Overall, there is slight increase in the composition of recyclables during the wet season, consistent with previous research by Gidarakos *et al.* (2006).

Comparing the waste composition of Bauchi during both the dry and wet seasons, shown in Figure 3.2, reveals distinct percentages for various waste categories. In the dry season, Bauchi's waste composition includes 47.1% food waste, 2.5% green waste, 3.3% paper, 7.7% textile, 16.5% plastics, 0.9% metals, 1% glass/ceramics, and 21% other waste. Conversely, during the wet season, the composition shifts slightly to 43.4% food waste, 3.4% green waste, 7.56% paper, 5.9% textile, 16.8% plastics, 3.7% metals, 2.96% glass/ceramics, and 16.3% other waste.

Despite a decrease in the percentage of food waste and textile during the wet season in Bauchi, a slight increase in the amount of recyclables is observed, aligning with patterns observed in Kaduna and previous studies. Although there is no apparent seasonal effect on the amount of food waste, it is evident that food waste occupies the largest fraction of the waste stream in both Bauchi and Kaduna, highlighting the potential for composting and biological conversion for biogas production. (Zia *et al.* 2017). Furthermore, the percentages of food waste fractions for both Bauchi and Kaduna correspond to values typical for developing countries, as documented by Alabdraba & Al-Qaraghully (2013). These findings emphasize the importance of implementing waste management strategies tailored to the specific composition and seasonal variations observed in urban areas like Bauchi and Kaduna, to effectively address waste challenges and promote sustainable practices.

Statistical Analysis of the Solid waste composition and seasonal variation

Analysis of Variance Test

The results showing the two-way analysis of variance (ANOVA) for Kaduna and Bauchi considering the dry and wet seasons and the income level of the household are presented in Table 3.12 to Table 3.15

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Table 3.12. Result of two-way Analysis of variance for Kaduna Household in Dry Season

Source of Variation	SS	df	MS	F	P-value	F crit
Household	0.170133	14	0.012152	0.964548	0.509991	2.063541
Income Level	0.466893	2	0.233447	18.52891	7.48E-06	3.340386
Error	0.352773	28	0.012599			
Total	0.9898	44				

Table 3.13. Result of two-way Analysis of variance for Kaduna Household in Wet Season

Source of Variation	SS	df	MS	F	P-value	F crit
Household	0.33368	14	0.023834	1.124057	0.381005	2.063541
Income Level	0.452493	2	0.226247	10.6701	0.000359	3.340386
Error	0.593707	28	0.021204			
Total	1.37988	44				

Table 3.14. Result of two-way Analysis of variance for Bauchi Household in Dry Season

Source of Variation	SS	df	MS	F	P-value	F crit
Household	0.091613	14	0.006544	0.924391	0.545847	2.063541
Income Level	0.258653	2	0.129327	18.26894	8.37E-06	3.340386
Error	0.198213	28	0.007079			
Total	0.54848	44				

Table 3.15. Result of two-way Analysis of variance for Bauchi Household in Wet Season

Source of Variation	SS	df	MS	FCAl	P-value	F crit
Household	0.214098	14	0.015293	1.748625	0.101257	2.063541
Income Level	0.486524	2	0.243262	27.81553	2.22E-07	3.340386
Error	0.244876	28	0.008746			
Total	0.945498	44				

Table 3.12 & 3.13 show that for Kaduna state in dry and wet season, Income level had significant effect on the waste generated with (F_{CAL} = 27.8155> F_{CRIT} =3.3404) and (F_{CAL} = 10.6701>F_{CRIT} =3.3404) for dry and wet season respectively. Also, Table 3.14 & 3.15 show that for Bauchi state in dry and wet season, Income level had significant effect on the waste generated with (F_{CAL} = 18.2689> F_{CRIT} =3.3404) and (F_{CAL} = 27.8155> F_{CRITs} =3.3404) for dry and wet season respectively.

Therefore, the ANOVA results for all seasons show that the level of income which is High income, middle income and the low income has effect on the average waste generated within the two states.

t – test Analysis

The results showing the t-test analysis of wet and dry season for High, Middle and Low income levels in Kaduna and Bauchi are shown in Table 3.16 to 3.21.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(1), MARCH, 2025
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

Table 3.16. Result of t-test of wet and dry season for High income in Kaduna

	Dry	wet
Mean	0.484	0.592
Variance	0.020668571	0.021246
Observations	15	15
Pearson Correlation	0.424307439	
Hypothesized Mean Difference	0	
df	14	
t Stat	-2.692637368	
P(T<=t) one-tail	0.008753605	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.01750721	
t Critical two-tail	2.144786688	

Table 3.17. Result of t-test of wet and dry season for Middle income in Kaduna

	dry	wet
Mean	0.3364	0.4216
Variance	0.008490667	0.021872
Observations	25	25
Pearson Correlation	0.38354842	
Hypothesized Mean Difference	0	
df	24	
t Stat	-3.019126014	
P(T<=t) one-tail	0.002964889	
t Critical one-tail	1.71088208	
P(T<=t) two-tail	0.005929778	
t Critical two-tail	2.063898562	

The Pearson Correlations between the wet and dry season in Kaduna which are 0.424307439, 0.38354842 and 0.132213473 for High, Middle and Low income groups respectively as shown in Table 3.16, 3.17 and 3.18 indicate a moderate to week positive correlation. The null hypothesis is typically that there's no significant difference between the means of the wet and dry seasons while the alternative hypothesis is that there is a significant difference between the wet and dry season. Since the p-value (0.01750721, 0.005929778 and 0.005929778) for High, Middle and Low income groups respectively are less than the common significance level of 0.05, we reject the null hypothesis and conclude that there is significant difference between the wet and dry season. The negative t-statistic (-2.692637368, -3.019126014 and -4.164020218) for High, Middle and Low income groups respectively indicates that the mean of the wet condition is significantly higher than the mean of the dry condition.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Table 3.18. Result of t-test of wet and dry season for Low income in Kaduna

	dry	wet
Mean	0.2445	0.332
Variance	0.01001161	0.020247
Observations	60	60
Pearson Correlation	0.132213473	
Hypothesized Mean Difference	0	
df	59	
t Stat	-4.164020218	
P(T<=t) one-tail	5.16426E-05	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	0.000103285	
t Critical two-tail	2.000995378	

Table 3.19. Result of t-test of wet and dry season for High income in Bauchi

	dry	wet
Mean	0.354	0.432
Variance	0.013197143	0.014889
Observations	15	15
Pearson Correlation	0.603740815	
Hypothesized Mean Difference	0	
df	14	
t Stat	-2.859618743	
P(T<=t) one-tail	0.006304195	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.01260839	
t Critical two-tail	2.144786688	

The Pearson Correlations between the wet and dry season in Bauchi which are 0.603740815, -0.012457 and 0.12597098 for High, Middle and Low income groups respectively as shown in Table 3.19, 3.20 and 3.21 indicate a moderate to week positive correlation. The null hypothesis is typically that there's no significant difference between the means of the wet and dry seasons while the alternative hypothesis is that there is a significant difference between the wet and dry season. Since the p-value (0.01260839, 0.00887182and 0.013743974) for High, Middle and Low income groups respectively are less than the common significance level of 0.05, we reject the null hypothesis and conclude that there is significant difference between the wet and dry season. The negative t-statistic (-2.859618743, -2.8483355 and -2.539849286) for High, Middle and Low income groups respectively indicates that the mean of the wet condition is significantly higher than the mean of the dry condition.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Table 3.20. Result of t-test of wet and dry season for Middle income in Bauchi

	dry	wet
Mean	0.2396	0.3112
Variance	0.00431233	0.011311
Observations	25	25
Pearson Correlation	-0.012457	
Hypothesized Mean Difference	0	
df	24	
t Stat	-2.8483355	
P(T<=t) one-tail	0.00443591	
t Critical one-tail	1.71088208	
P(T<=t) two-tail	0.00887182	
t Critical two-tail	2.06389856	

Table 3.21. Result of t-test of wet and dry season for Low income in Bauchi

	dry	wet
Mean	0.174666667	0.2175
Variance	0.006337175	0.013016
Observations	60	60
Pearson Correlation	0.12597098	
Hypothesized Mean Difference	0	
df	59	
t Stat	-2.539849286	
P(T<=t) one-tail	0.006871987	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	0.013743974	
t Critical two-tail	2.000995378	

Multiple Regression Analysis

The multiple regression analysis was carried out on the household and the various level of income which are High income, middle income and the low income and the results of the analysis is shown in Table 3.22.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Table 3.22. Result of regression Analysis for Kaduna and Bauchi Household in two Season

State	Season	Regression Equation	R^2	R
Kaduna	Dry	$WG = 19.21 - 6.61HI - 10.21MI - 18.85LI$	0.2055	0.4533
	Wet	$WG = 5.78 - 5.75HI + 5.99MI + 8.53LI$	0.0653	0.2555
Bauchi	Dry	$WG = 22.47 - 18.97HI - 31.47MI - 0.43LI$	0.3525	0.5937
	Wet	$WG = 13.05 - 9.74HI + 1.80MI - 7.85LI$	0.1147	0.3387

WG= Waste Generated, HI = High income, MI=Middle income and LI= Low income

The result shows that for both Kaduna and Bauchi state the dry season regression equation is the best model to predict the waste generated.

CONCLUSION

The study examines extensively the effect of seasons as in dry and wet season and the income level on solid waste generation rates in Kaduna and Bauchi. During the dry season, the high-income group exhibited the highest solid waste generation rate of 0.484 kg/capita/day, followed by the middle and low-income group with 0.34 kg/capita/day and 0.24 kg/capita/day respectively. Similarly, during the wet season, this trend persisted, with the high-income group generating the most waste at 0.59 kg/capita/day, followed by the middle-income group with 0.42 kg/capita/day, and the low-income group with 0.33 kg/capita/day.

The combined waste generation rate for Kaduna was found to be higher during the wet season compared to the dry season, with average rates of 0.44 kg/capita/day and 0.35 kg/capita/day, respectively. The total average generation rate during the dry season was 0.25 kg/capita/day, while during the wet season, it increased to 0.32 kg/capita/day. This suggests a higher generation of waste during the wet season compared to the dry season.

The ANOVA results shows that the level of income has effect on the waste generation for both Kaduna and Bauchi across the season. Also the t- test results show significance of seasons on solid waste generation rates in both Bauchi and Kaduna with higher rates in wet seasons. The multiple regression analysis shows that for both Kaduna and Bauchi state the dry season regression equation is the best model to predict the waste generated.

REFERENCES

Abdussalam, A. A., Abdulkareem, S. B., Idris, M., & Jumare, D. M. (2023). Assessment of Kaduna State Primary Health Care Board financial management capacity on primary health care service delivery in Kaduna State, Nigeria. *KIU Journal of Social Sciences, 9*(3), 17–26.

Abel, A. (2007). An analysis of solid waste generation in a traditional African city: The example of Ogbomoso, Nigeria. *Environment and Urbanization, 19*(2), 527–537.

Adeleke, O. A., Akinlabi, S. A., Jen, T. C., & Dunmade, I. (2021). An overview of factors affecting the rate of generation and physical composition of municipal solid waste. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1107, No. 1, p. 012096). IOP Publishing.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Adeniyi, L. A., & Afon, A. O. (2022). Seasonal quantification and characterization of solid waste generation in tertiary institution: A case study. *Journal of Material Cycles and Waste Management, 24*(3), 1172–1181.

Afon, A. O., & Okewole, A. (2007). Estimating the quantity of solid waste generation in Oyo, Nigeria. *Waste Management & Research, 25*(4), 371–379.

Aguilar-Virgen, Q., Taboada-González, P., & Ojeda-Benítez, S. (2013). Seasonal analysis of the generation and composition of solid waste: Potential use—a case study. *Environmental Monitoring and Assessment, 185*, 4633–4645.

Alabdraba, W. M. S., & Al-Qaraghully, H. A. (2013). Composition of domestic solid waste and the determination of its density & moisture content: A case study for Tikrit city, Iraq. *International Review of Civil Engineering, 4*(2), 1–6.

Amori, A. A., Fatile, B. O., & Omoregbe, H. O. (2013). Waste generation in residential areas of Nigerian tertiary institutions. *Journal of Education and Social Research, 3*(4), 45–51.

Corona, B., Shen, L., Reike, D., Carreón, J. R., & Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling, 151*, 104498.

Denafas, G., Ruzgas, T., Martuzevičius, D., Shmarin, S., Hoffmann, M., Mykhaylenko, V., ... & Ludwig, C. (2014). Seasonal variation of municipal solid waste generation and composition in four East European cities. *Resources, Conservation and Recycling, 89*, 22–30.

Fereja, W. M., & Chemeda, D. D. (2022). Status, characterization, and quantification of municipal solid waste as a measure towards effective solid waste management: The case of Dilla Town, Southern Ethiopia. *Journal of the Air & Waste Management Association, 72*(2), 187–201.

Gidarakos, E., Havas, G., & Ntzamilis, P. (2006). Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. *Waste Management, 26*, 668–679.

Gómez, G., Meneses, M., Ballinas, L., & Castells, F. (2009). Seasonal characterization of municipal solid waste (MSW) in the city of Chihuahua, Mexico. *Waste Management, 29*, 2018–2024.

Iacovidou, E., Velis, C. A., Purnell, P., Zwirner, O., Brown, A., Hahladakis, J., ... & Williams, P. T. (2017). Metrics for optimising the multi-dimensional value of resources recovered from waste in a circular economy: A critical review. *Journal of Cleaner Production, 166*, 910–938.

Jadoon, A., Batool, S. A., & Chaudhry, M. N. (2014). Assessment of factors affecting household solid waste generation and its composition in Gulberg Town, Lahore, Pakistan. *Journal of Material Cycles and Waste Management, 16*, 73–81.

Kayode, A. M., & Omole, F. K. (2011). Some socio-economic factors affecting solid wastes generation and disposal in Ibadan metropolis, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries, 3*(1), 55–64.

Khan, D., Kumar, A., & Samadder, S. R. (2016). Impact of socioeconomic status on municipal solid waste generation rate. *Waste Management, 49*, 15–25.

Liu, J., Li, Q., Gu, W., & Wang, C. (2019). The impact of consumption patterns on the generation of municipal solid waste in China: Evidences from provincial data. *International Journal of Environmental Research and Public Health, 16*(10), 1717.

Masebinu, S. O., Akinlabi, E. T., Muzenda, E., Aboyade, A. O., Mbohwa, C.,

Corresponding author: Rabia Lawal Batagarawa
✉ *rlbatagarawa@nda.edu.ng*
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.

Manyuchi, M., & Naidoo, P. (2017). A review on factors affecting municipal solid waste generation.

Mshelia, A. D. (2015). Seasonal variations of household solid waste generation in Mubi, Nigeria. *International Journal of Innovative Education and Research, 3*(5), 115–124.

Ogwueleka, T. C. (2013). Survey of household waste composition and quantities in Abuja, Nigeria. *Resources, Conservation and Recycling, 77*, 52–60.

Oluwole, S. O. (2015). Socio-economic correlates of household solid waste generation: Evidence from Lagos Metropolis, Nigeria. *Management Research and Practice, 7*(1), 44–54.

Ori, P. U., Adebowale, A., Umeokonkwo, C. D., Osigwe, U., & Balogun, M. S. (2021). Descriptive epidemiology of measles cases in Bauchi State, 2013–2018. *BMC Public Health, 21*, 1–11.

Owamah, I. H., Izinyon, O. C., & Igbinewekan, P. (2017). Characterization and quantification of solid waste generation in the Niger Delta Region of Nigeria: A case study of Ogbe-Ijoh community in Delta State. *Journal of Material Cycles and Waste Management, 19*, 366–373.

Ozcan, H. K., Guvenc, S. Y., Guvenc, L., & Demir, G. (2016). Municipal solid waste characterization according to different income levels: A case study. *Sustainability, 8*(10), 1044.

Roberts, C., Watkin, G., Phillips, P., & Odunfa, A. (2010). Seasonal variation and municipal solid waste composition—Issues for development of new waste management strategies in Abuja, Nigeria. *The Journal of Solid Waste Technology and Management, 36*(4), 210–219.

Senzige, J. P., Makinde, D. O., Njau, K., & Nkansah-Gyeke, Y. (2014). Factors influencing solid waste generation and composition in urban areas of Tanzania: The case of Dar-es-Salaam.

Sharma, K. D., & Jain, S. (2020). Municipal solid waste generation, composition, and management: The global scenario. *Social Responsibility Journal, 16*(6), 917–948.

Sikder, S., Toha, M., & Mostafizur Rahman, M. (2024). An overview on municipal solid waste characteristics and its impacts on environment and human health. In *Technical Landfills and Waste Management: Volume 1: Landfill Impacts, Characterization and Valorisation* (pp. 135–155).

Zeng, Y., Trauth, K. M., Peyton, R. L., & Banerji, S. K. (2005). Characterization of solid waste disposed at Columbia Sanitary Landfill in Missouri. *Waste Management & Research, 23*(1), 62–71.

Zia, A., Batool, S. A., Chauhdry, M. N., & Munir, S. (2017). Influence of income level and seasons on quantity and composition of municipal solid waste: A case study of the capital city of Pakistan. *Sustainability, 9*(9), 1568.

Corresponding author: Rabia Lawal Batagarawa
rlbatagarawa@nda.edu.ng
Department of Civil Engineering Nigerian Defence Academy, Kaduna Nigeria.