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Original Research Article

Solid Waste Generation and Disposal Among Household Residents in Benin Development and Planning Authority (BDPA) Housing Estate, Benin City, Nigeria

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ABSTRACT

This study therefore assessed solid waste generation and disposal among households in the Bendel Development and Planning Authority (BDPA) housing estate in Benin City, Edo State, Nigeria. Data for the study were collected via a structured questionnaire and waste sample collection. Waste sample collection was used to obtain data on the quantity and composition of waste generated in the BDPA estate, while the questionnaire was used to obtain data on the waste disposal methods practiced in the study area. The findings from the studies revealed that the quantity of solid waste generated in the BDPA estate on a daily basis is quite high, with values ranging from 112.39 to 184.04 kg/day. The waste produced consists of seven primary components: bottles, paper, plastics, polythene, metals, organic waste (food waste), and miscellaneous materials. The study indicated that organic waste (36.44%) accounted for the majority of the solid waste generated in BDPA, followed by plastic (29.48%), miscellaneous materials (24.67%), polythene (4.21%), bottles (4.08%), papers (0.98%), and metals (0.13%), which is the least solid waste generated. The major waste disposal method practiced in BDPA Estate is open dumping of waste. Open dumping, though cost-effective, significantly harms the environment and public health. Hence, other waste disposal practices should be encouraged in the estate.

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1. INTRODUCTION

Solid waste management is the different approaches and procedures designed and implemented to identify, control, and handle the different types of waste from generation until disposal (Mubaslat, 2021). The techniques involved ensure the orderly execution of the functions of collection, processing, and disposal of solid waste (Sincero and Sincero, 2010). Solid waste is continually growing, and many countries are increasingly concerned about protecting the environment and natural resources through sustainable waste management programs (Kumar et al., 2017; Ugwu et al., 2018). Global waste generation rates are rising.

Over 2 billion tons of municipal waste are produced annually (WHO, 2023). According to the World Bank (2022), the world produced 2.24 billion metric tons of municipal waste in 2020, amounting to a footprint of 0.79 kilograms per capita per day; this is expected to increase by 73% from 2020 levels to 3.88 billion metric tons in 2050 due to rising population and urbanization. The most significant growth is expected to happen in developing countries, including Sub-Saharan African countries, where many face the challenges of poorly managed waste (Ayeleru et al., 2020; Azevedo et al., 2021; WHO, 2023; World Bank, 2023).

Nigeria faces a major challenge in waste management. Despite various policies implemented in the last 30 years, most urban areas still suffer from poor waste disposal (Ugorji et al., 2020). Waste dumps are common on open lands, farmlands, river banks, major roads, and streets. These practices cause environmental problems such as land degradation, vector breeding grounds, offensive odors, emissions of toxic gases, and groundwater contamination if not managed properly, as Farasat et al. (2015) and Ike et al. (2018) observed. They can also produce leachates that contain heavy metals, microorganisms, and radioactive elements (Egharevba et al., 2013; Olusegun, 2013). Vulnerable groups, such as children, are at increased risk of adverse health outcomes from poor waste management. E-waste, such as TVs, computers, and phones, is created at a high rate of 54 million tons per year (2019 data) and is expected to reach 75 million tons by 2030 (WHO, 2023). Only 17% of e-waste was properly collected and recycled in 2019. Children can be exposed to e-waste and its components that are not managed well, and this can cause many health and developmental issues.

A major challenge for proper waste management and disposal is the absence of reliable data on the amount and types of waste produced and discarded. This data is vital for designing and implementing effective waste management strategies, such as waste reduction, reuse, recycling, and recovery. It also helps to assess the environmental and economic outcomes of waste management practices, such as greenhouse gas emissions, resource use, landfill space, and waste management costs (ECCC, 2022; World Bank, 2023). This data is severely lacking in Nigeria (Ugorji et al., 2020). This knowledge gap hinders the planning and management of waste in the country. A case in point is Benin City, with many tourism potentials, where the sector is currently threatened by poor waste management. Attempts to implement an integrated solid waste management program are obstructed by the lack of updated data on the amount of waste generated and disposed of in the area (Ugorji et al., 2020). Although some studies have tried to characterize solid waste in Benin City and also estimated the amount of waste generation (Igbinomwanhia, 2012; Onwuemele, 2015), these studies cover only some parts of Benin City, excluding areas like the BDPA housing estate in the Ugbowo district of Benin City. Therefore, considering that different regions have different waste generation rates and compositions (World Bank, 2023), this study aims to estimate solid waste generation and evaluate the disposal method in the BDPA in the Ugbowo district of Benin City using a combination of field surveys (questionnaires) and waste sampling. This will contribute to the existing knowledge on the amount of solid waste generation in other parts of Benin City to improve the management of solid waste in the city. This will help to improve solid waste management in the Benin City, thereby creating a healthier and more sustainable future for all.

2. METHODOLOGY

2.1. Study Area

The Benin Development and Planning Authority (BDPA) housing estate is located in the Ugbowo district, opposite the University of Benin, in the Ovia North-East Local Government Area (LGA) of Benin City, Nigeria. The LGA is situated between latitudes 5° 15' and 6° 45' north and longitudes 5° 45' and 6° 15' east of the central province of Edo State, covering an area of 2,301 square kilometers (Akinbo and Okaka, 2010). The region experiences a mean annual rainfall of between 1500mm and 2500mm and a mean monthly temperature varying from 25°C to 28°C (Ancient Benin Kingdom and Edo State, 2018; Rawlings and Seghosime, 2022). The geology of the region is marked by reddish earth composed of ferruginized or literalized clay sand (Ikhile, 2016). It is underlain by the sedimentary formation of the South Sedimentary Basin and constitutes part of the Benin formation, which is made up of over 90% massive, porous, coarse

sand with thick clay and shale interbeds having high groundwater retention capacity (Ikhile, 2016; Adegbite et al., 2018). Ovia North-East LGA has a population of 153,849 persons (NPC, 2006); the actual population of BDPA estate as of this time is yet to be ascertained.

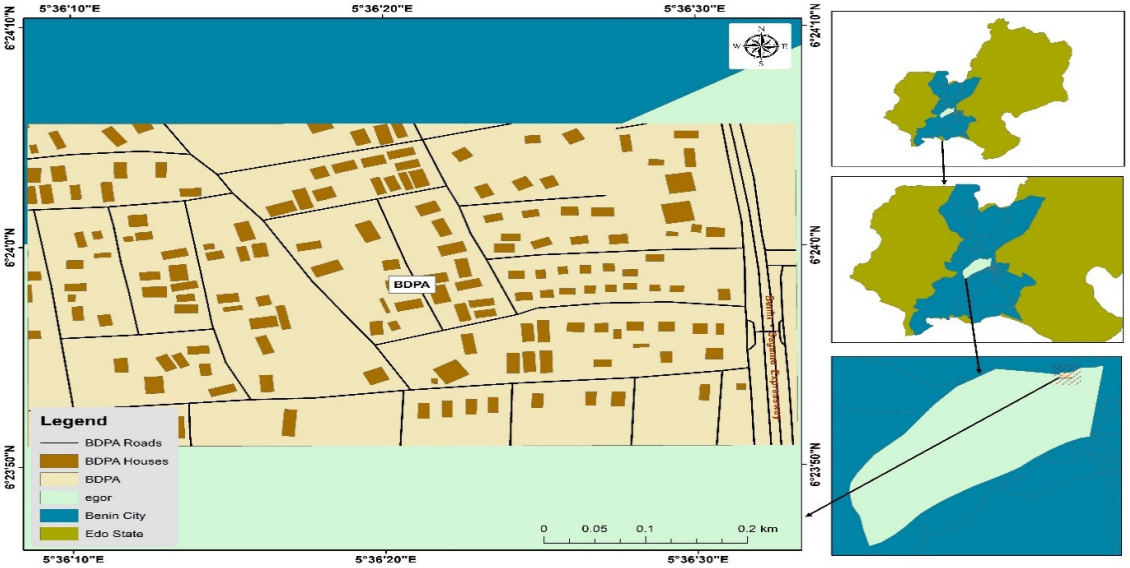

Figure 1: Aerial map of the study area (Andre-Obayanju and Ireaja, 2022- Modified by Authors, 2024).

2.2. Data Collection

Data collection was carried out in the study area via a structured questionnaire and waste sample collection.

2.3. Solid Waste Generation Rate and Characterization

The amount of waste generated in the BDPA estate was estimated in this study using quantification at the point of waste collection. This is due to the inaccessibility of the BDPA estate's actual population, the lack of records, and the absence of a well-organized system for collecting solid waste in the estate. Using this approach, the waste was sorted, weighed, and categorized. Although BDPA Estate is made up of a variety of structures, including two-story buildings and bungalows with numerous units, about 100 apartments consented to take part in the study; thus, these apartments were given plastic bags to collect the waste they produced on a daily basis and, as such, served as the collection location. The targeted apartments were provided with two plastic bags, each labeled as organic and inorganic waste. Every morning, the waste generated was collected, sorted (by hand with the use of gloves), individual components were weighed (using a weighing scale), and replaced with new bags. This activity was conducted for a duration of seven days, as suggested by Rushbrook and Pugh (2004) and Ugorji et al. (2020). The materials contained in the solid waste were sorted accordingly into 7 categories, namely: bottles, papers, plastics, polythene, metals, organic waste (food waste), and miscellaneous materials. The various solid waste components at each collection location were aggregated, respectively, and then summed all together to obtain the total amount of waste generated daily. The percentage composition of the solid waste components was estimated using Equation (1), as specified by Spangler (2018):

$$\%\ composition\ of\ solid\ waste\ component = \frac{Weight\ of\ solid\ waste\ component\ generated}{Total\ weight\ of\ solid\ waste\ generated} \times 100 \quad (1)$$

2.4. Waste Disposal Methods

Information on waste disposal methods and practices in the study area was obtained through observation and a questionnaire. A total of about 100 technically designed, pre-tested, structured questionnaires were administered to households in the BDPA estate using a simple random sampling technique. The study population consisted of about 100 households in the BDPA estate (precisely those that were used to quantify the solid waste generated). To ensure the validity of the questionnaire, the face validity method was used to ascertain about 15% of the questionnaire. Its reliability was assessed using Cronbach's alpha statistics, which is a measure used to assess the internal consistency of a set of scales or test items and normally ranges between 0 and 1 (Goforth, 2022). The questionnaire was structured to capture the socio-demographic characteristics of respondents, their knowledge, and their methods of waste disposal. A total of 100 completed copies of questionnaires were retrieved and analyzed. The retrieved questionnaires and Cronbach's alpha reliability were analyzed using Statistical Package for the Social Sciences (SPSS, version 26.0, 2018), and the results were presented using descriptive tables. The sample size used for the study was determined using Equation 2 (Yamane, 1967), as adapted from Rawlings and Seghosime (2022):

$$n = \frac{N}{1+Ne^2} \tag{2}$$

Where n = Sample size, N = Population under study and e = Margin error=0.05

3. RESULTS AND DISCUSSION

3.1. Quantity and Physical Composition of Solid Waste Generated in BDPA Estate

The results of the quantity and composition of solid waste generated in the BDPA estate are presented in Tables 1 and 2. Table 1 indicates the daily solid waste generation in the BDPA estate, and Table 2 shows the percentage composition of solid waste generated in the BDPA estate for a week.

Table 1: Daily solid waste generation in the BDPA estate

Days	Components							Daily total (kg/day)
	Bottles	Papers	Plastics	Polythene	Metals	Organic waste	Miscellaneous materials	
Monday	2.43	1.59	33.01	8.58	0.45	40.65	25.68	112.39
Tuesday	6.29	1.52	42.32	4.52	0.34	51.36	24.68	131.03
Wednesday	6.51	1.33	39.39	6.51	0.08	51.15	35.89	140.86
Thursday	6.74	1.29	29.63	5.12	0.08	46.25	30.70	119.81
Friday	6.98	1.30	49.45	6.16	0.08	52.54	40.99	157.50
Saturday	5.64	1.36	52.46	5.37	0.16	57.31	51.35	173.65
Sunday	7.04	1.62	54.18	6.63	0.17	72.21	42.19	184.04
Week total (kg/week)	41.63	10.01	300.44	42.89	1.36	371.47	251.48	1019.28

From Table 1, results indicated that the quantity of solid waste generated in the BDPA estate on a daily basis is quite high, with values varying from 112.39 to 184.04 kg/day, and for a week per component, values varied from 1.36 to 371.47 kg/week. The rate of waste generation in an area depends on a number of factors, such as population density and size, income, the season of the year, and the local customs of the people (Ugorji et al., 2020). As such, the high quantity of waste generated on a daily basis in the BDPA estate may have been influenced by any of these factors. Waste generation varied on a daily basis; it was observed that lesser quantities were generated during the weekdays (Monday to Thursday) while larger quantities were generated during the weekends (Friday to Sunday). Monday (112.39 kg/day), Tuesday (131.03 kg/day), and Thursday (119.81 kg/day) have the least total waste generated per day, while Friday (157.50 kg/day), Saturday (173.65 kg/day), and Sunday (184.04 kg/day) have the highest total waste generated per day. These

results implied that the rate of waste generated during the week differs from that generated during the weekends. Similar patterns of waste generation at the household level have also been observed by studies (Thanh et al., 2010; Jadoon et al., 2014; Dikole and Letshwenyo, 2020; Ugorji et al., 2020). The daily variance in waste generation in the BDPA estate may have been impacted by the residents' way of life (Dikole and Letshwenyo, 2020). The activities that take place on Friday, Saturday, and Sunday may be the cause of the increased waste output throughout the weekend. The majority of individuals in BDPA Estate, which is primarily home to University of Benin (Uniben) students, plan and host parties on Fridays and Saturdays, and on Sundays they spend the day on weekly clean-up. In addition, the majority of individuals shop for food on the weekends to stock their homes for that weekend and the upcoming weekdays (Thanh et al., 2010).

Table 2: Percentage composition of solid waste generated in the BDPA estate for a week

Components	Generation rate (kg/week)	Composition of waste (%)
Bottles	41.63	4.08
Papers	10.01	0.98
Plastics	300.44	29.48
Polythene	42.89	4.21
Metals	1.36	0.13
Organic waste	371.47	36.44
Miscellaneous materials	251.48	24.67

The findings presented in Table 2 reveal that the characteristics of the waste generated are similar to those found in most cities in Nigeria, and for a week, organic waste (36.44%) accounted for the majority of the solid waste generated in BDPA estate, followed by plastic (29.48%), miscellaneous materials (24.67%), polythene (4.21%), bottles (4.08%), papers (0.98%), and metals (0.13%), which is the least solid waste generated. Food waste, particularly on the part of children and students, may be the cause of the higher generation rate of organic waste (food waste), and this is also suggesting a culture of cooking large quantities of food as an essential need for people (Kadir and Abidin, 2015; Dikole and Letshwenyo, 2020). Children may resort to food abuse when their parents are at work because of unsupervised cooking. Since most students do not experience a food shortage at home, the fact that they always receive food supplies from their parents may be the cause of food waste. Research has indicated that the majority of solid waste generated in households is composed of organic waste (Babatunde et al., 2013; Owamah et al., 2017; Mohd-Rodzi et al., 2019; Dikole and Letshwenyo, 2020; Rawlings and Seghosime, 2023).

After organic waste, plastic, miscellaneous materials, and polythene wastes were the second, third, and fourth most prevalent components. The presence of plastic and polythene wastes suggests that the wastes are from packaging food, water, and other products that inhabitants purchase from markets and commercial areas. The majority of the time, plastic is used to package soft drinks, liquor, and water. In addition, they are employed in the production of home furnishings like buckets, dishes, chairs, and other utensils. This could explain why there are so many plastics in the waste generated by households in the BDPA estate. The low quantity of polythene waste recorded may indicate a reduction in the usage of sachet water (sanitized water packed in a polythene bag) and polythene (water-proof) bags in the study area. In this study, miscellaneous material waste refers to a combination of other types of water apart from the categories considered. Their increase in generation may have been influenced by lifestyle changes, economic factors, and region (Zhou et al., 2014). As this study has shown, domestic waste has also been discovered to include a high rate of plastic components (Babatunde et al., 2013; Dikole and Letshwenyo, 2020; Ugwu et al., 2020; Rawlings and Seghosime, 2023).

Paper and metal are the least common components of waste generated in the BDPA estate. While the adoption of digital alternatives may account for the low incidence of paper waste, the low rate of metal waste

may indicate that residents consume fewer processed foods and can drinks. This result suggests that residents have a culture of reducing waste at the source.

Waste characterization enables the proper planning of solid waste management (Abur et al., 2014). Therefore, considering the large proportion of organic waste found in the study, the feasibility of composting organic waste should be evaluated since it might be a source of fertilizer that can be used to maximize agricultural output in the study area. In addition, a high percentage of plastic may inspire locals in the study area to recycle and earn money for themselves.

3.2. Waste Disposal Methods

The results obtained from the questionnaire survey on waste disposal methods in the BDPA estate are presented in Tables 3 to 5. Table 3 shows the Cronbach's alpha for the reliability of the questionnaire; Table 4 indicates the socio-demographic characteristics of respondents; and Table 5 indicates the knowledge and methods of waste disposal practice in the BDPA estate. According to Table 1's Cronbach's alpha value of above 70%, every question on the questionnaire appears to be comparable and pertinent to the survey's subject. It therefore suggests an excellent questionnaire. Table 4 showed that the respondents belonged to a variety of age categories, including youths, adults, and the elderly. The majority of the respondents (89%) were between the ages of 18 and 40; 10% were between the ages of 41 and 65; and 1% were older than 65 years. The low participation of the elderly (above 65 years) may be owing to the fact that the BDPA estate is occupied mainly by Uniben students. About 66% of respondents were female and 34% were male; 72% of respondents were single, 27% were married, and only 1% were divorced. The study further revealed that the respondents were literate, as the majority (69%) attended tertiary institutions, 18% had adult education, 10% had secondary education, and 3% had only primary education. Of the respondents, 58% worked for the private sector, 23% for the government (civil servants), 8% were farmers, 6% were self-employed, 2% owned businesses or traders, and 3% were not gainfully employed despite their level of education. The majority of respondents—54%—are middle-class earners, making an average monthly income of between ₦20,000 and ₦100,000; 26% are low earners, making an income of less than ₦20,000; and 20% make above ₦100,000 (high earners).

Based on Table 5, most respondents (79%) said they were familiar with the terms "solid waste" and "solid waste disposal." About 47% of the respondents reported that solid waste consisted of unwanted materials, 29% of discarded materials, 6% of useless materials, and 2% of unusable materials. This high level of awareness regarding solid waste may be attributed to the respondents' generally high educational status (Adogu et al., 2015). Also, most of the respondents claimed that they disposed of waste using a variety of methods, such as open dumping, recycling, burning, composting, and throwing it into the bush. A large proportion of the respondents (35%) dumped their waste at an open dumpsite, 22% recycled it, 15% burned it, 5% composted it, 4% threw it in a bush, and 19% disposed of their waste through other means. This result agrees with the findings from previous studies, where it was reported that the majority of households dispose of their waste at open dumpsites (Adogu et al., 2015; Girsha et al., 2016; Inah et al., 2020; Rawlings and Seghosime, 2022). In developing countries, open dumping remains the most prevalent and straightforward method for disposing of municipal solid waste (MSW) (Aderemi and Falade, 2012). The widespread use of open dumpsites can be attributed to limited budgets for waste disposal and a lack of trained personnel, as highlighted by Ali et al. (2014). However, open dumping is an inappropriate and uncontrolled waste disposal practice that poses significant risks to public health and the environment, as emphasized by Asuma (2013), Liu et al. (2017), and Rawlings and Seghosime (2022). Therefore, it is crucial for households to adopt best practices in waste management. A sizeable number of respondents who indicated that they are practicing recycling are participating in the collection phase of recycling, where they collect plastic bottles and sell them to local re-users. This practice should be encouraged, as results from waste characterization revealed that a high percentage of plastic waste is generated in the BDPA estate. The practice will help divert waste

from dumpsites (reduce dumpsite waste), conserve resources, and contribute to proper waste management (by mitigating pollution).

Table 3: Cronbach's alpha for the reliability of questionnaire

Cronbach's Alpha	No. of items
0.742	11

Table 4: Socio-demographic characteristics of the respondents (n=100)

Variables	Number of respondents	Percentage
Age (years)		
18-40	89	89.0
41-65	10	10.0
Above 65	1	1.0
Total	100	100.0
Gender		
Male	34	34.0
Female	66	66.0
Total	100	100.0
Marital status		
Single	72	72.0
Married	27	27.0
Divorced	1	1.0
Total	100	100.0
Education level		
Adult education	18	18.0
Tertiary education	69	69.0
Secondary education	10	10.0
Primary education	3	3.0
Total	100	100.0
Employment level		
Unemployed	3	3.0
Self Employed	6	6.0
Farmer	8	8.0
Business/trader	2	2.0
Private worker	58	58.0
Public worker (civil servant)	23	23.0
Total	100	100.0
Monthly income		
High income earner (Above ₦100,000)	20	20.0
Middle income earner (₦20,000-₦100,000)	54	54.0
Low income earner (Below ₦20,000)	26	26.0
Total	100	100.0

The majority of the respondents (46%) reported daily waste disposal, 34% disposed of waste weekly, 16% did so monthly, and 4% at irregular intervals. These findings suggest commendable hygiene practices within households. Additionally, a significant 66% expressed their willingness to engage in solid waste management programs and training. Such participation is essential for enhancing their understanding of waste management, which, in turn, can positively impact their environment and overall health.

Table 5: Knowledge and methods of waste disposal practice in BDPA estate

Variables	Number of Respondent	Percentage
Are you familiar with the word solid waste and solid waste disposal?		
Yes	79	79.0
No	21	21.0
Total	100	100.0
What is Solid waste?		
Discarded solid materials	29	29.0
Unwanted solid materials	47	47.0
Unusable solid materials	2	2.0
Useless solid materials	6	6.0
Don't Know	16	16.0
Total	100	100.0
Solid waste disposal method practice		
Opening dumping	35	35.0
Burning	15	15.0
Throwing into the bush	4	4.0
Composting	5	5.0
Recycling	22	22.0
Others	19	19.0
Total	100	100.0
Frequency of waste disposal		
Daily	46	46.0
Weekly	34	34.0
Monthly	16	16.0
Others	4	4.0
Total	100	100.0
Willingness to participate in solid waste management programs/trainings		
Yes	66	66.0
No	34	34.0
Total	100	100.00

4. CONCLUSION

This research has examined the volume, attributes, and waste disposal techniques employed by households in the BDPA housing estate of Benin City, Edo State, Nigeria. The study revealed that the quantity of solid waste generated in the BDPA estate on a daily basis is quite high, with values varying from 112.39 to 184.04 kg/day. Waste generation varied on a daily basis; it was observed that lesser quantities were generated during the weekdays (Monday to Thursday) while larger quantities were generated during the weekends (Friday to Sunday). The waste produced consists of seven primary components: bottles, paper, plastics, polythene, metals, organic waste (food waste), and miscellaneous materials. The study indicated that organic waste (36.44%) accounted for the majority of the solid waste generated in the BDPA estate, followed by plastic (29.48%), miscellaneous materials (24.67%), polythene (4.21%), bottles (4.08%), papers (0.98%), and metals (0.13%), which is the least solid waste generated. The major waste disposal method practiced in BDPA Estate is open dumping of waste. Open dumping, though cost-effective, significantly harms the environment and public health. Emissions from open dumping introduce hazardous substances like dioxins, furans, and mercury into the air, water, and soil, contributing to pollution. As such, other waste disposal practices should be encouraged in the community. The findings from this study strongly indicate the necessity of adopting composting and recycling methods of waste disposal, as high percentages of organic (food) and plastic wastes were generated in the study area. It is crucial to proactively pursue these initiatives

through organizing solid waste management programs and training, as residents are willing to engage in such activities to enhance waste management practices in the community.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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