World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

Geospatial assessment of the efficiency of waste disposal facilities in Lugbe, FCT

Nazifa Musa Bauka *, Monica Ndidi Onumaegbu, Epsar Philip Kopteer, Vivian Chisom Nwabughiogu, Chinenye Ann Nweke, Vivian Aaron Ibrahim, Jibatswen Agbutsokwa Hosea and Philip Okoh Amodu

National Space Research and Development Agency (NASRDA), Nigeria.

World Journal of Advanced Research and Reviews, 2024, 22(03), 885–901

Publication history: Received on 04 May 2024; revised on 13 June 2024; accepted on 15 June 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.3.1797

Abstract

Solid waste consists of substances or objects that are disposed of and are mostly found where there are human activities, these substances are accumulations of waste materials generated from domestic, commercial, and industrial operations that are deemed unworthy or rejected and required to be disposed of. The study aims to assess the efficiency of waste disposal facilities in Lugbe FCT, with specific objectives to; evaluate the spatial distribution of waste collection sites (dumpsites) in the area, evaluate the proximity of dumpsites (waste collection sites) to the residential areas, and evaluate the level of appropriate use of waste bins in the study area. Both primary and secondary data were used for this study. The primary data used are the X and Y coordinates of dumpsite locations and questionnaire administration while the secondary data includes; the Google Earth image. Nearest neighbour analysis was performed on the dumpsite's coordinate locations to affirm its spatial distribution pattern in the study area. Buffering analysis was performed on the dumpsite locations with 300m standard to identify the proximity of dumpsites to buildings while the descriptive statistical method was used to analyze the retrieved administered questionnaires to assess the level of the appropriate use of waste bins in the study area. The result of the dispersed spatial distribution of the dumpsites and the result of the proximity analysis performed on dumpsites to the residential area revealed that buildings were found around almost all the dumpsites except the Park Estate dumpsite where no building is found around the dumpsite. At the level of waste bin appropriateness, all the waste bin types were adopted but 72% of waste bin types are appropriate.

Keywords: Geospatial; Dumpsites; Waste-bin; Google Earth; Average Nearest Neighbour; Proximity

1. Introduction

Solid waste is found where there is human activity and the accumulation of waste materials generated from domestic, commercial, and industrial operations that are deemed unworthy or rejected and required to be disposed of [1]; [2]. According to [3], waste is substances or objects that are disposed of or are intended to be disposed of by the provision of the national law. Solid waste is any unwanted or discarded material that is not liquid or gas [4]. According to [5], solid waste includes; durable goods, non-durable goods, containers and packaging wastes, food wastes and yard trimmings, and miscellaneous inorganic wastes [5]. Thus, municipal solid waste is an accumulation of rejects from households, market women, traders, shop owners, and other commercial activities in urban areas. The composition and characteristics of municipal solid waste are influenced by certain factors, which include the area (residential, commercial), the economic level (differences between high and low-income areas), the season and weather, and the culture of people living or doing business in the area.

Municipal Solid Management (MSWM) is the process where sorting, storage, collection, transportation, processing, resource recovery, recycling, and disposal of waste in certain areas [4]. The fundamental target of solid waste management (SWM) is to protect the health of the population, promote environmental quality, develop sustainability, and provide support to economic productivity through utilization of waste as a resource [6]. Solid Waste Management

* Corresponding author: Nazifa Musa Bauka

has remained an intractable environmental problem in developing nations, which has manifested in the form of piles of indiscriminately disposed heaps of uncovered waste and illegal dumpsites along major roads and at street corners in cities and urban areas [7]. It has been compounded by the rapid urbanization and population growth which led to the generation of enormous quantities of solid waste which are often discarded by open dumping. Generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced [8].

However, solid waste production has increased globally due to the following reasons; population growth, economic growth, and associated consumption behaviour [9; 10]. Global municipal solid waste (MSW) generation levels are approximately 1.3 billion tons per year and 1.2 Kg per person per day. They are expected to increase to approximately 2.2 billion tons per year by 2025 [11]. OECD countries produce half of the world's waste, while Africa and South Asia Regions produce the least waste [12]. Most dumpsites in the world are situated in Africa, Asia Latin America, and Caribbean with two in Europe and they pose serious health and environmental threats [13].

Furthermore; the avert of GIS technology has been recognized as one of the most promising approaches to automate the process of waste planning and management. GIS technology has been successfully used for sites of recycling drop-off centers, optimizing waste management, estimation of solid waste generation using local demographic and socioeconomic data, and waste generation forecasting at the local level [14]. Almost all factors related to solid waste management has both spatial and non-spatial components and for an efficient management system, remote sensing technology provides information about the various spatial criteria such as land use/land cover, drainage density, slope, road network, existing locations of municipal bins and for positioning dumpsites [15]; [16]. The creation of digital geodatabase and other geospatial analysis such as; spatial clustering process, facility route analysis, query and buffering operations will help the municipal officers to identify, monitor and to easily understand; solid waste dumping site selection process, easy access to the condition of waste disposal units type, optimal location of community waste bins, location of waste disposal units and the movement of the waste in the bins to waste disposal unit type [17]; [18]; [19].

Municipal solid waste management has emerged as one of the greatest challenges facing environmental protection agencies in developing countries and over 90% of waste, especially in these countries is often disposed of in unregulated dumps or openly burned and the study area is not exempted [20]; [21].

Abuja has witnessed a huge influx of people into the city which resulted in a continuous increase in the volume of solid waste generated in the Federal Capital City (FCC) which has risen to 400,000kg per day from year 2014. Due to the continuous increase in the volume of solid waste generation in Abuja, the study area has been experiencing several illegal creations of open dump sites which have exposed the area to rat breeding sites, fly infestation, water and air pollution, disease outbreaks, health hazards and has damaged the aesthetic beauty. Furthermore, the attitude of the residents in the study towards environmental protection and cleanliness is still questionable where the residents still litter the streets and roads with all sorts of solid wastes, majorly due to their lackadaisical attitudes and sometimes due to inadequacy of waste-bins or not sufficient enough for the quantity of waste generated.

Solid waste contributes to; 5% of the total greenhouse gas (GHG) emission into the atmosphere, air pollution from waste burning and leachates generated as a result of the decomposition of waste from the dumpsites into nearby surface water and underground water [22]; [23]. There are major risks associated with waste dumpsites such as; fire hazards and explosions, public health risks, and environmental degradation [7].

Waste management is a global challenge that requires innovative solutions, and utilizing geospatial technology can provide valuable insights into the effectiveness of current waste management practices. There is a need to understand and improve waste management practices in Lugbe area, a rapidly growing urban community facing various environmental challenges. By conducting a geospatial assessment, researchers can analyze and visualize spatial patterns of waste generation, collection, and disposal, as well as identify areas of inefficiency or potential improvement. One of the key reasons for choosing Lugbe area as the focus of this study is its unique geographical and socio-economic characteristics. As a peri-urban community located on the outskirts of Abuja, the capital city of Nigeria, Lugbe area experiences a complex mix of urban and rural dynamics that influence waste management practices. By examining these factors within a geospatial framework, researchers can develop targeted interventions to enhance waste management efficiency and sustainability. The use of geospatial technology allows researchers to integrate various data sources, such as satellite imagery, GPS tracking, and demographic information, to create comprehensive spatial models of waste management processes. This holistic approach enables a deeper understanding of the spatial relationships between waste generation, collection infrastructure, and environmental impacts, which can inform evidence-based decision-making and policy development.

This study aims to assess the efficiency of waste disposal facilities in Lugbe FCT with specific objectives; to evaluate the distribution of waste collection sites in my study area; to evaluate the proximity of dumpsites in my study area to residential buildings; and to characterize the level of the appropriate use of waste-bins in the study area.

1.1. Study Area

1.1.1. Geographical characteristics

Lugbe is located within the Abuja Municipal local government of the FCT and the town is divided into five (5) districts; Lugbe North, South, Central, West, and East. It lies between Latitude 8˚56'0" N and 8˚58'0" N and Longitude 7˚21'0" E and 7˚23'0" E It is largely populated with more residential facilities (figure 1).

1.1.2. Physical characteristics

The study area enjoys a tropical continental climate characterized by two distinct seasons; the dry and rainy seasons. The rainy season spans March/April to September/October, while the dry season extends from October to May. The mean annual rainfall is 1630mm, while temperatures vary from 22^{o}C around December/January to 35^{o}C in March/April [24]. Vegetation is characterized by thorn bushes and trees, herbs, shrubs, and mango trees, the area being in Guinea Savannah Vegetation zone of Nigeria. The study area is located within the Central Nigeria Precambrian Basement Complex and the rocks comprise; mostly granite, gneisses, mica schists, and hornblende [24].

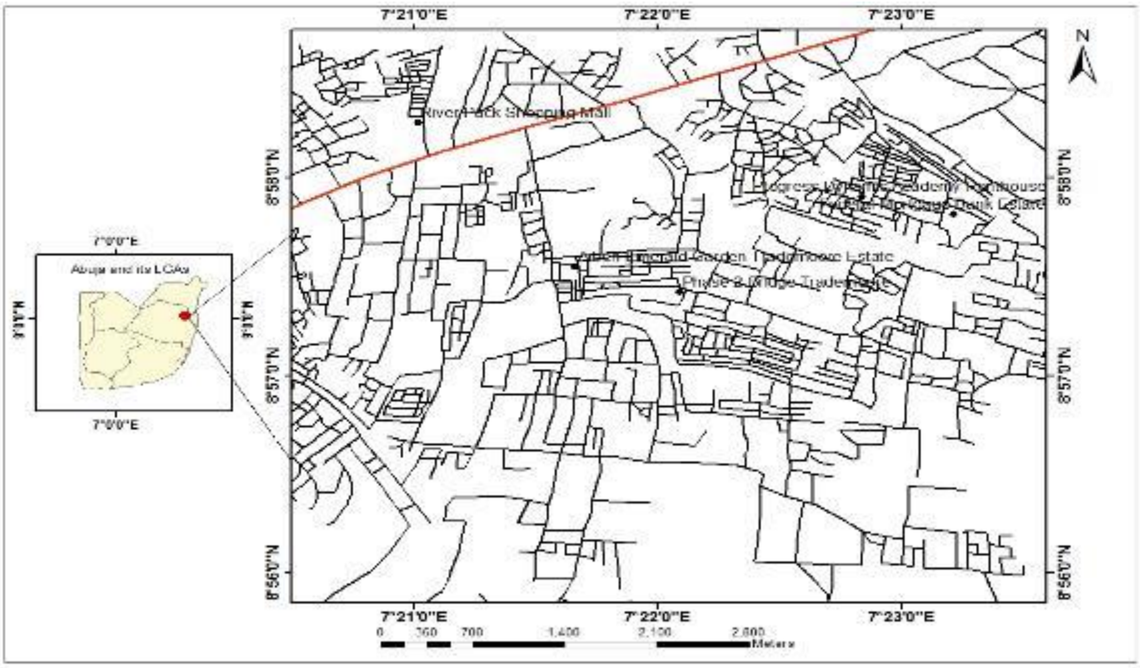

Figure 1 Map of Study Area

2. Materials and method

This section shows different datasets and methods adopted to achieve all the stated objectives of the study.

2.1. Data types and sources

The data types used for this research consist of primary and secondary data. Primary data used includes; the dumpsites X and Y coordinate and the questionnaire administration. The dump site coordinate locations describe the spatial positioning of all the dumpsites surveyed in the study. This is accomplished on the field using the global positioning system equipment and the coordinate system type was set to decimal degrees for easy locational mapping. Questionnaire administration was used to assess the information on the appropriate use of waste bins.

The secondary data used for this study includes; Google Earth imagery which was acquired from the Google Earth website with the usage of clearly depicting and extracting of road network in the study area.

2.2. Questionnaire Administration

The questionnaire was administered using the random sampling technique. Random sampling has the greatest freedom from bias but may represent the costliest sample in terms of time and energy for a given level of sampling error. This shows that every case of the population has an equal probability of inclusion in the sample. Sixty (60) respondents were randomly selected for this study, and all the retrieved papers were checked on the appropriate answering of questions and completion of it by the respondents. Data were entered into an Excel sheet according to the code given to each option and checked if there were omissions before proceeding into analysis using SPSS software package.

2.3. Analysis

2.3.1. Evaluating the distribution of waste collection sites in the study area

Dumpsite mapping was done identifying all the dumpsites on the field. Hand-held Global Positioning System receiver instrument was used to pick the geographical coordinates of all the dumpsite locations in the study area. All the coordinates were inputted into an excel sheet and imported into GIS environment, the coordinate locations were plotted and spread in the GIS environment for easy visualization.

The spatial distribution of the dumpsites was done using the average nearest neighbour model (ANN). The average nearest neighbour model is an ordinal statistic that reports the existence and degree of clustering or dispersion of locations (geometric points). The average nearest neighbour model is a member of a family of cluster-measuring statistics and this model is considered a distance analytical statistic because it strictly measures proximity between locations. This method yields an index called the Rate neighbourhoods (Rn), which ranges from zero to 2.15. The closer the value of Rn is to zero indicates the cluster distribution pattern. The closer the value of Rn is to 2.15 indicates a regular distribution pattern, and the number 1 expresses the random spatial distribution. In the Average Nearest Neighbour method, if the index is less than 1, the distribution is clustered, and if the index is greater than 1, there is a tendency to disperse. The Average Nearest Neighbor method is very sensitive, and a small change in the distribution of land use can cause many changes in the computations [25].

Average Nearest Neighbor = $\frac{Distance}{number\ of\ Points}$ --- equation 1

Expected Average Nearest Neighbor = $(1/2* \sqrt{\frac{Area}{number\ of\ Points}})$ ---------------------equation 2

Z score = (d) $\frac{\text{Average NN – Expected}}{Standard\ Deviation}$ --equation 3

Nearest Neighbor Index = $\frac{\text{Average NN}}{Expected}$ --- equation 4

Rate neighborhood = $\frac{\text{Observed Distance}}{Expected\ Distance}$ --equation 5

If R < 1 then: pattern exhibits clustering

If R > 1 then: pattern is ordered

2.3.2. Evaluate the proximity of dumpsites (waste collection sites) to the residential areas

This was achieved using the proximity analysis, 30 meters buffered around all of the dumpsites.

2.3.3. Evaluate the level of appropriate use of waste-bin in the study area

Quantitative statistical analysis was adopted to achieve this objective. The descriptive method was used to get the frequency and percentage, used to check the level of appropriate use of waste bins in the study area.

Table 1 Data type, Source, Year, and Usage

S/N	Data Type	source	Year	usage
1	Satellite Image	Google Earth website	2021	Extraction of road network
2	Waste collection sites coordinate	Fieldwork	2021	Geographical Location of dump sites in the study area
3	Waste bins coordinate	Fieldwork	2021	Geographical Location of waste bins in the study area
4	Questionnaire's	Fieldwork	2021	Respondent's perception of the waste bin adoption

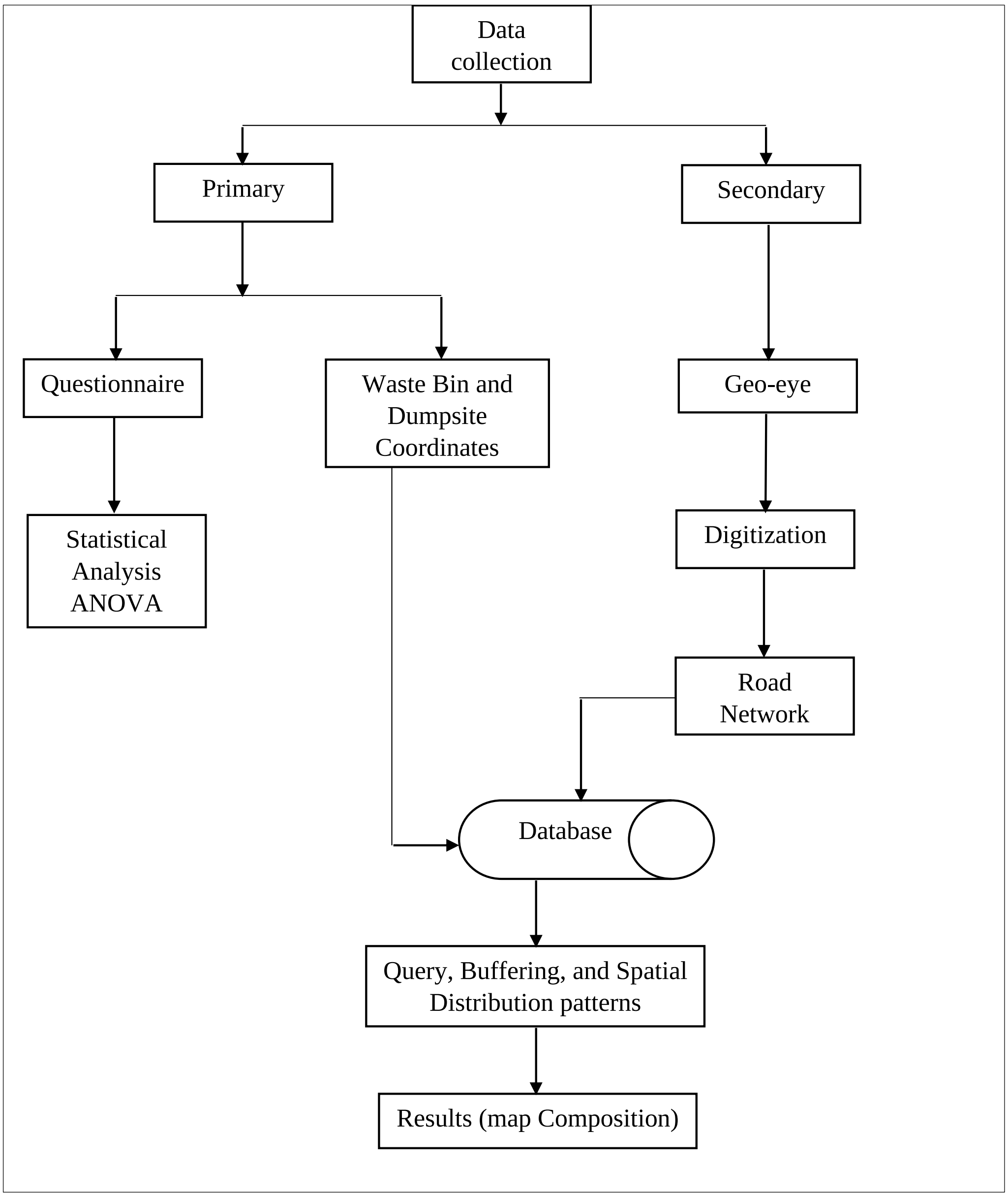

Figure 2 Methodology Workflow

3. Results and discussion

3.1. Evaluating the distribution of waste dumpsites

The dumpsites in the area were located and mapped using the global positioning system (GPS) and the finding shows that six dump sites were located in the study area (Table 2). The acquired coordinates were imported into ArcGIS environment where they were plotted to see the spread with the area of study (Figure 3). However, the spatial distribution analysis known as the average nearest analysis was performed on the acquired locations. Figure 4 shows that dumpsites are dispersed within the study area at the Z-score of 335.6, the nearest neighbour ratio of 72.6 with a p-value of 0.01. When the Z score which is the critical value is greater than 2.58, the dumpsite is dispersed. This could be because those dumpsites apart from the main Lugbe dumpsite were created by chance of disposing of the debris indiscriminately in a space with the interest of disposal.

Table 2 The Geographical characteristics and attributes of the dumpsites

S/N	Name	Location	Longitude	Latitude
1	Federal Mortgage Bank Estate	Lugbe	7.386917°	8.963568°
2	Progress Dynamic Academy Penthouse	Lugbe	7.380660°	8.965042°
3	River Pack Shopping Mall	Lugbe	7.350275°	8.971292°
4	Aiben Emerald Garden Trade Moore Estate	Lugbe	7.361003°	8.959137°
5	Phase 2 Bridge Trade Moore	Lugbe	7.368128°	8.957015°
6	Lugbe Dump Site	Lugbe	7.367587°	8.973715°

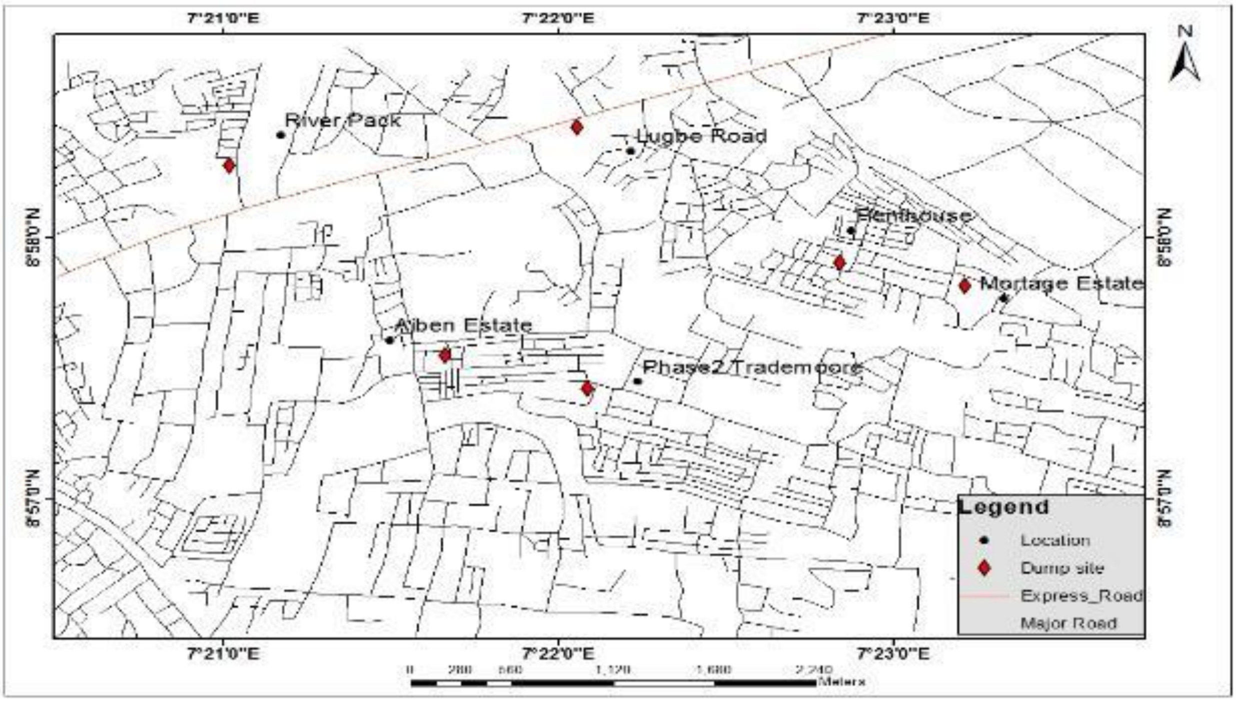

Figure 3 Dumpsites Distribution

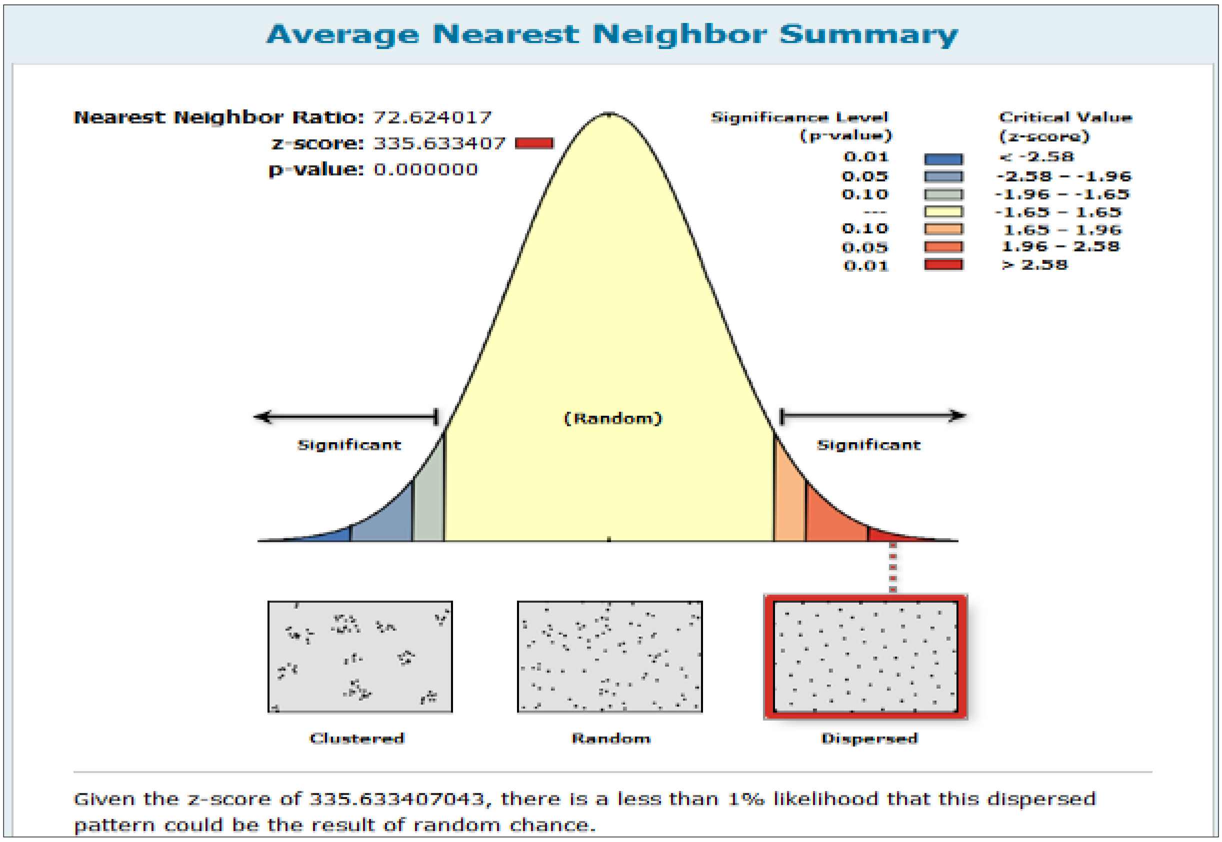

Figure 4 Dumpsites Spatial Distribution Pattern

3.2. Evaluate the proximity of dumpsites (waste collection sites) to residential area

Buffer analysis is a spatial analytic technique provided by GIS for creating new polygons around point, line, or area features of interest, to test for the proximity of the feature interest to another feature. The proximity of the dumpsite to the residential area was examined using a 300m buffered zone, which is a standard for siting a dumpsite to the residential area. Any building within this radius is not suitable to be located within the 300-buffered zone. Figure 5 - 10 checked the location of buildings within the 300m buffered zone of the six identified dumpsites and it was observed that there are buildings found within the buffered zone except the park estate dumpsite where no house is found within the zone.

Figure 5 Buffered of River Park dumpsite

Figure 6 Buffered of Lugbe dumpsite

Figure 7 Buffered of Aiben Estate

Figure 8 Buffered of Phase 2 Trade Moore Dumpsite

Figure 9 Buffered of Penthouse Estate

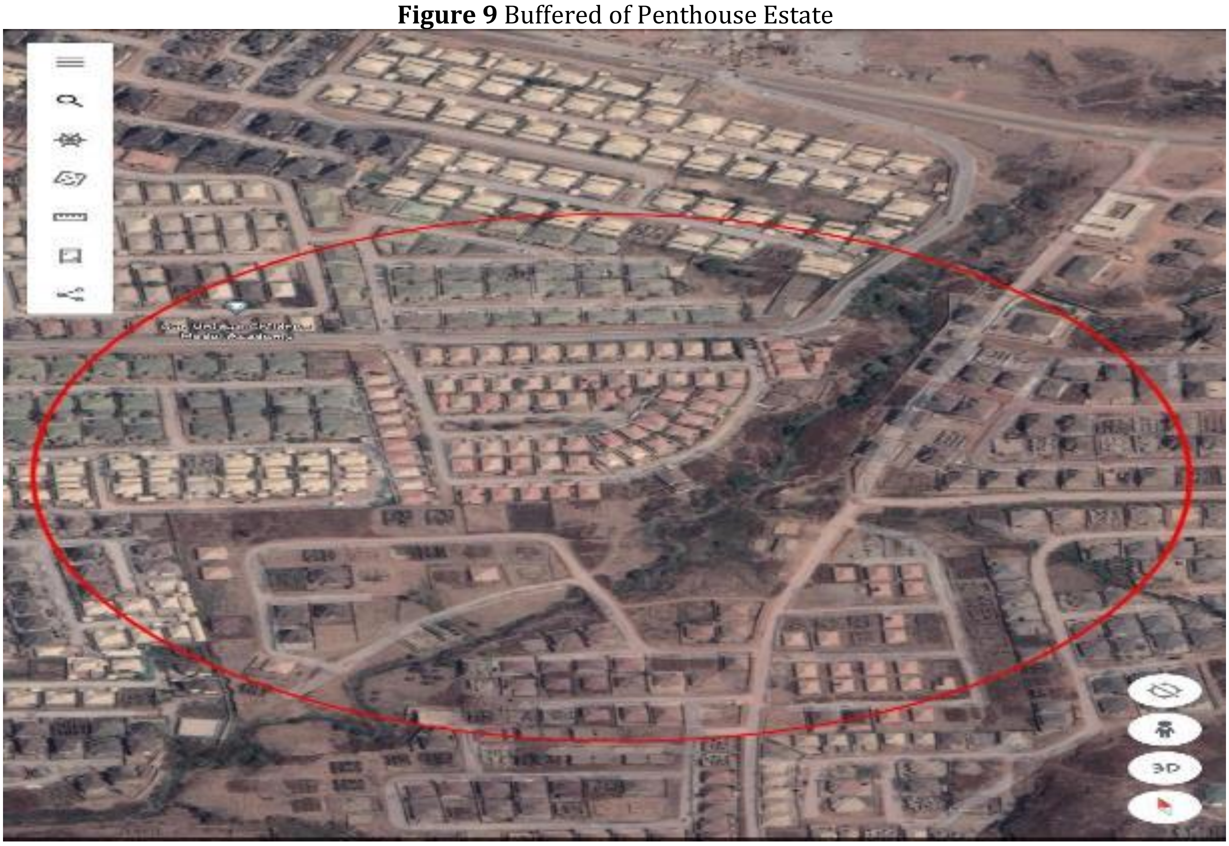

Figure 10 Buffered of Mortgage Bank Estate

3.3. Evaluating the level of adoption of waste-bin usage in the study area

This objective was achieved using questionnaire administration. A questionnaire administration method was used, 62 pieces of questionnaire were distributed and 60 were successfully retrieved. The socio-demographic characteristics of the respondents show that gender with males (44.8%) and females (55.2%) were samples where 17.5% were not educated, Primary school (5.3%) secondary school (26.3%) and larger population belonging to tertiary with 50.9 %.

The perceptions of the sampled respondents were analyzed regarding the adaptation of waste bins, using descriptive analysis such as the percentage and frequency. The waste bin type was categorized into five such as; sack/black bag, basket, metal container, plastic container, and private pit. According to Table 3 and Figure 12, 14.8% used sack/back bags to pack their waste, while the same set of respondents used baskets to pack their waste with a percentage of 6.6% and a higher percentage using metal and plastic waste bins with 24.5% and 47.5% while 6.6% used pits in managing their domestic wastes collection in preparation for disposal in the study area. The category of waste bin usage may be influenced by their occupation and educational level and this is confirmed by the work of [26]; [27]; [28] and [29]. Table 4.2 and Figure 11 confirmed the appropriate type of waste bins used in the study area which are plastic and metal type of waste bins.

Table 3 Respondent's Occupation and Waste Storage Types

Dumpsite Type	Frequency	Percentage (%)	Appropriateness
Sack/ black bag	9	14.8	Not appropriate
Basket	4	6.6	Not appropriate
Metal Container	15	24.5	Appropriate
Plastic Container	29	47.5	Appropriate
Private pit	4	6.6	Not Appropriate
Total	61	100	

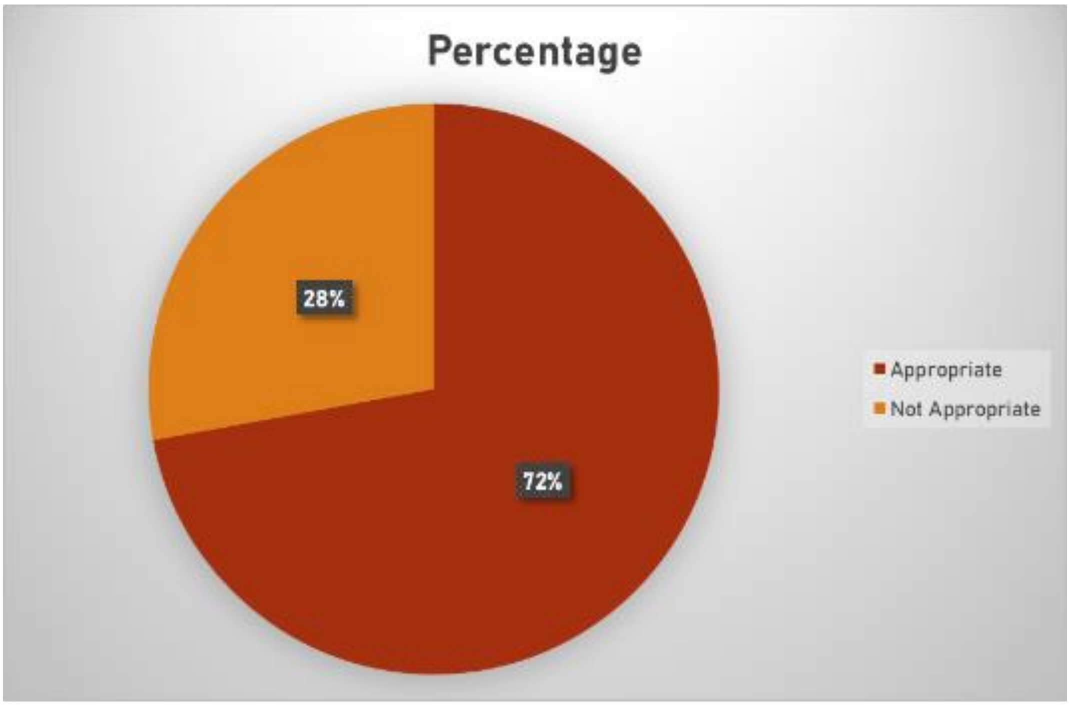

Figure 11 Level of Appropriateness

Figure 12 Frequency of waste type

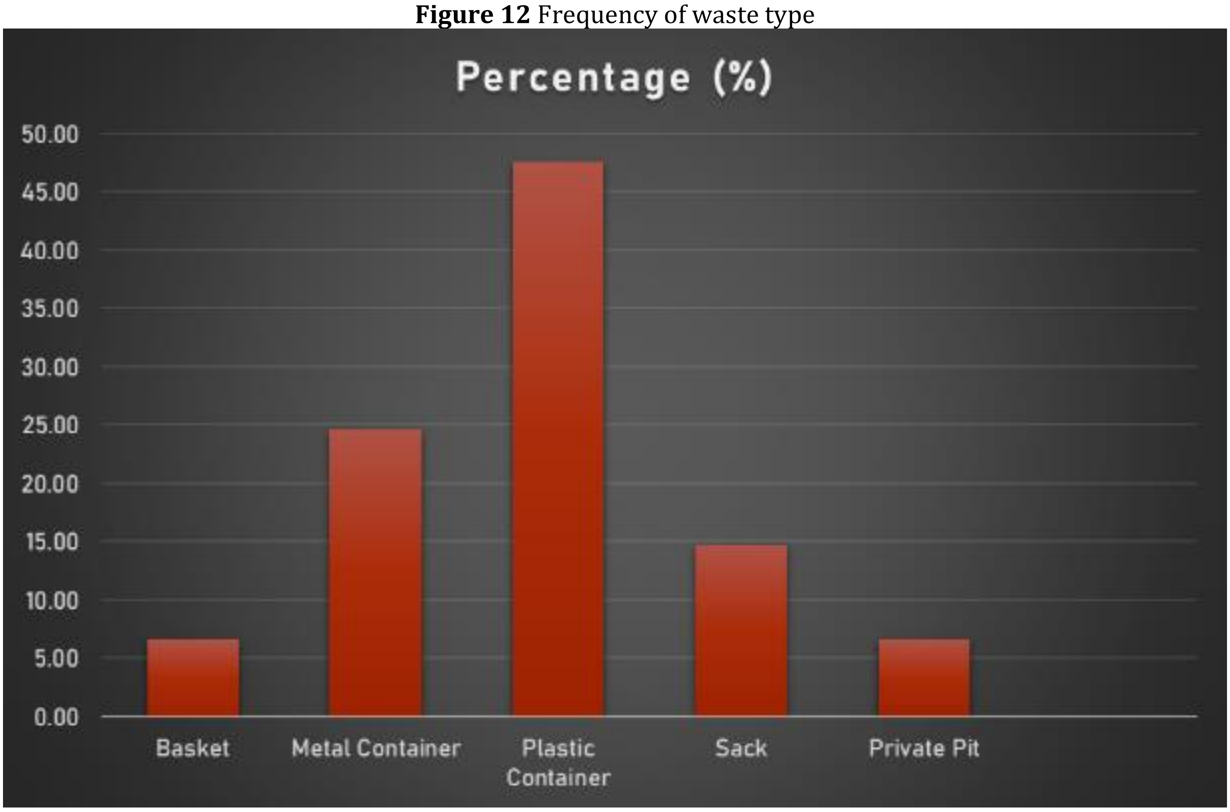

Figure 13 Percentage of waste type

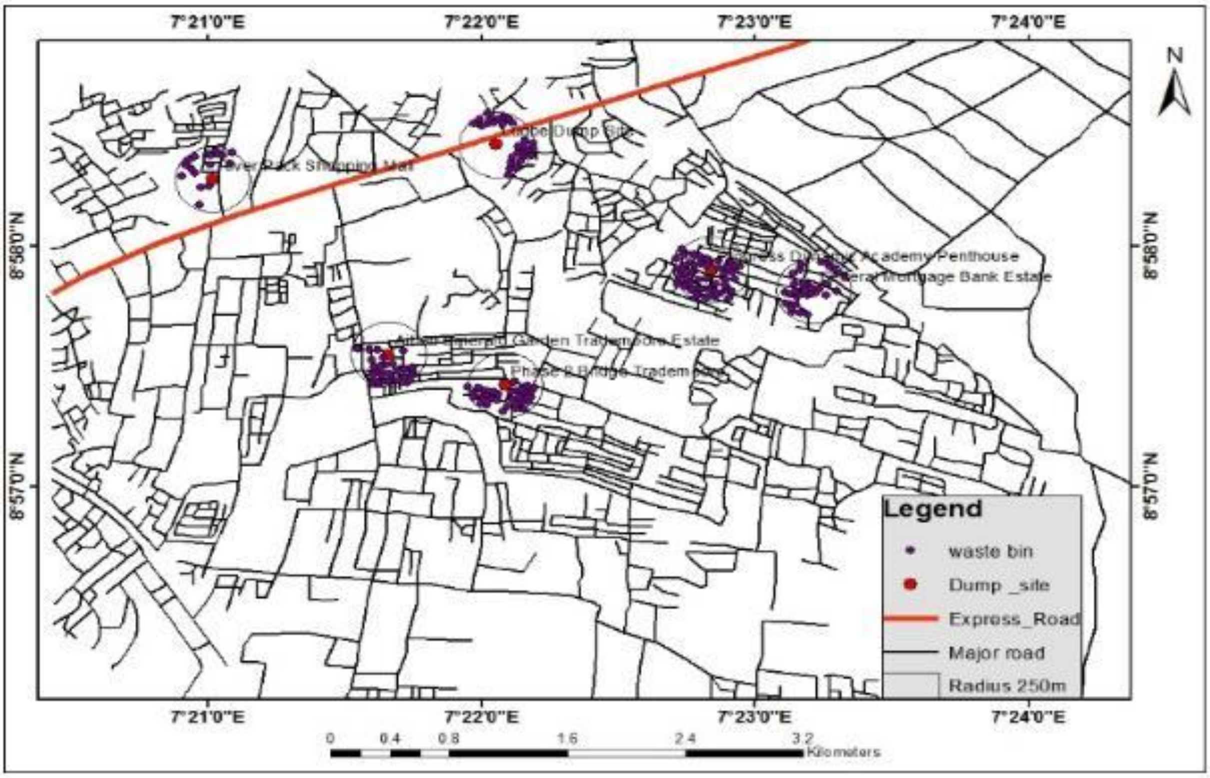

Figure 14 Waste bin survey

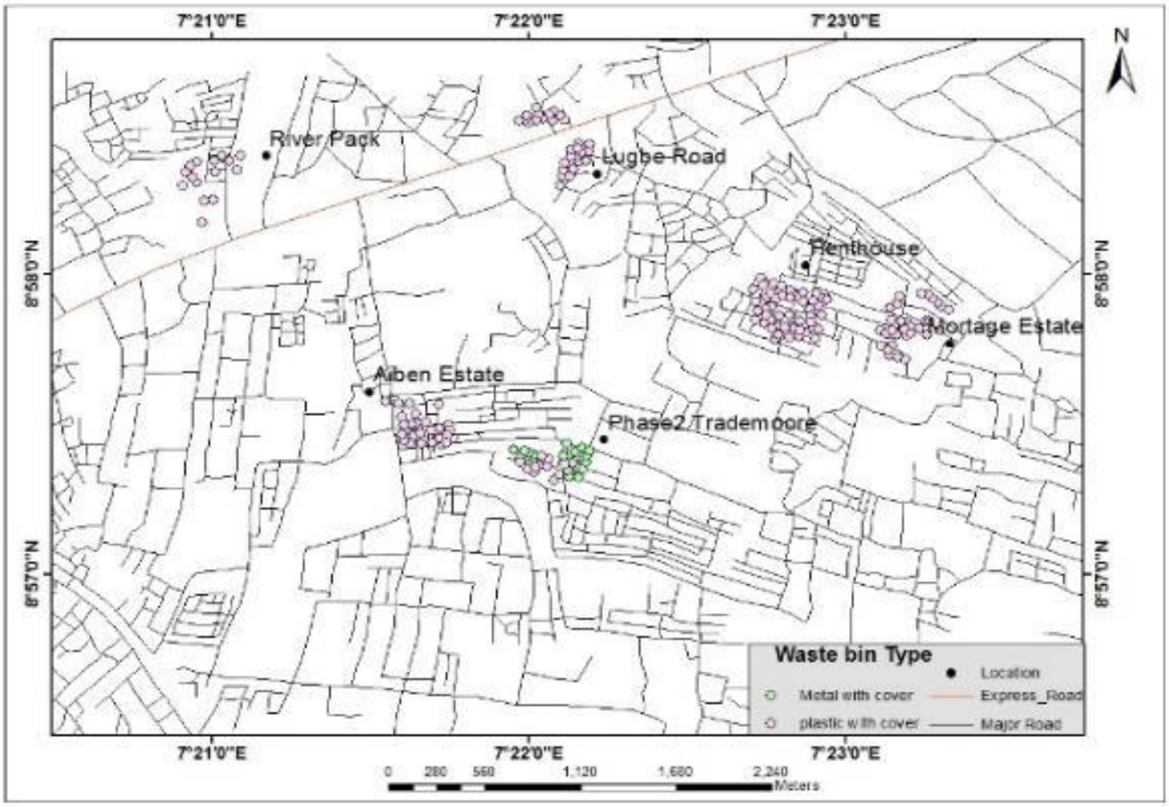

Figure 15 Waste bin type

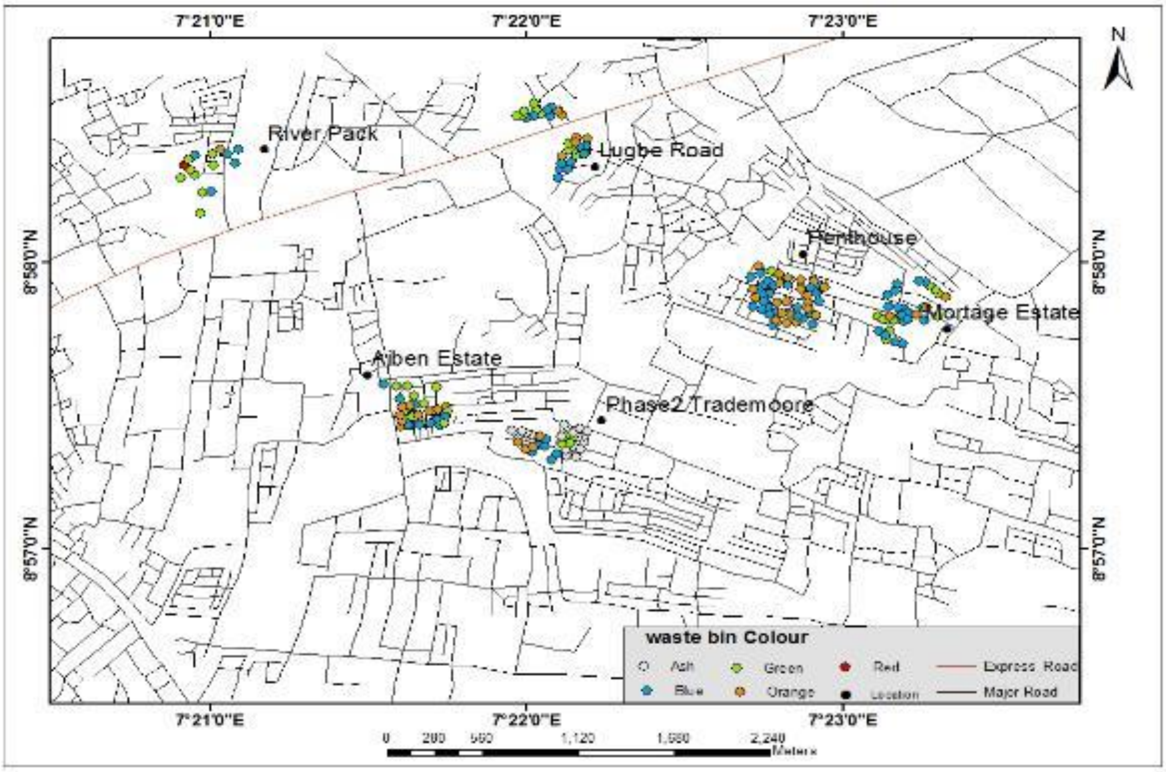

Figure 16 Waste bin type in colour

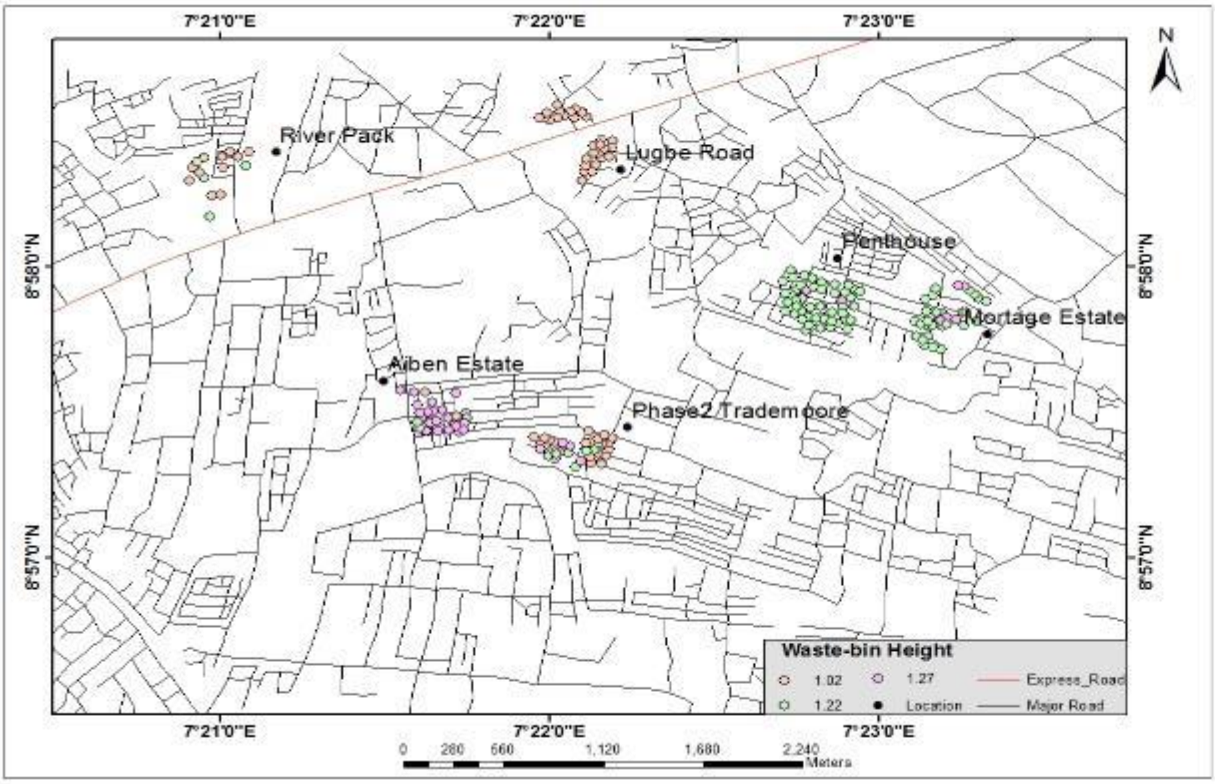

Figure 17 Waste bin Height

Table 4 Educational level of respondents in determining waste storage adoption

Waste bin	Not educated	Primary school	Secondary school	Tertiary	Total	F (p-value)
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)		
Sack/ black bag	4 (50.0)	4(50.0)	0 (0.0)	0 (0.0)	8	19.91 (0.00)
Basket	2 (66.7)	1 (33.7)	0 (0.0)	(0.0)	3	
Metal Container	0 (0.0)	0 (0.0)	3 (17.6)	14 (82.4)	17	
Plastic Container	3 (10.7)	1 (3.6)	6 (21.4)	18 (64.3)	28	
Private pit	1 (25.0)	2 (50.0)	1 (25.0)	0 (0.0)	4	
Total	10	8	10	32	60	

Table 5 Occupational level of respondents in determining waste storage adoption

Waste storage type	Civil servant	Farmer	Business	Student	Housewife	Total	F-value
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)		
Sack/ black bag	0 (0.0)	2 (22.2)	2 (22.2)	3 (33.4)	2 (22.2)	9	3.698 (0.01)
Basket	0(0.0)	3 (75.0)	0 (0.0)	1 (25.0)	0 (0.0)	4	
Metal Container	9 (60.0)	0 (0.0)	5 (33.3)	1 (6.7)	0 (0.0)	15	
Plastic Container	12 (41.4)	1 (3.5)	13 (44.8)	3(10.3)	0 (0.0)	28	
Private pit	0 (0.0)	2 (50.0)	1 (25.0)	1 (25.0)	0 (0.0)	4	
Total	21	6	21	9	2	60	

Table 6 Positioning of waste bin according to educational level of respondents

Positioning	Not educated	Primary school	Secondary school	Tertiary	Total	F-value
Along the road	1(50)	0 (0)	1(50)	0(0.0)	2	1.864 (0.132)
Back of the house	3 (27.3)	1 (9.0)	5 (45.5)	2 (18.2)	11	
Beside the house	0 (0.0)	0 (0.0)	0 (0.0)	1(100)	1	
Front of the building	0 (0.0)	0 (0.0)	1(33.7)	2 (66.7)	3	
Front of the gate	5 (13.5)	3 (8.1)	4(10.8)	25 (67.6)	37	
Total	9	4	11	30	54	

Table 7 Positioning of waste bin according to occupation of the respondents

Positioning	**Civil servant**	**Farmer**	**Business**	**Student**	**Housewife**	**Total**	**F-value (p-values)**
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)		
Along the road	1 (50.0)	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)	2	0.854 (0.501)
Back of the house	0	4 (36.4)	2 (18.2)	4 (36.4)	1 (9.0)	11	
Beside the house	0 (0.0)	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)	1	
Front of the building	2 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.7)	3	
Front of the gate	8 (36.4)	4 (18.2)	8 (36.4)	2 (9.0)	0 (0.0)	22	
Total	11	8	12	6	2	39	

4. Conclusion

The study examined waste bin disposal facilities in Lugbe, with the specific objectives which are to affirm the distribution of dumpsites, proximity of dumpsites to residential areas, and evaluation of waste bin adoption in the study area. The result in Figure 4 shows that the dumpsites are dispersed in the distribution pattern in the study area. When proximity analysis was done on dumpsites within a 300m standard buffer zone to the residential area, buildings were found around almost all the dumpsites except park estate dumpsites where no building is found around the dumpsites. At the level of waste bin adoption, all the waste bin types were adopted but metal waste bins took the highest percentage according to the respondent's view and the same type is the appropriate type of waste bin that should be used (Table 3).

Recommendations

Data collection and conducting a geospatial assessment of waste disposal facilities in Lugbe is paramount to include information on the location of waste disposal facilities, the types of waste being disposed of, and the capacity of each facility. In addition, data on population density, land use patterns, and environmental factors should be collected to provide a comprehensive understanding of the waste management situation in the area.

Geographic Information Systems (GIS) mapping is a powerful tool that can be used to analyze and visualize spatial data. Creating maps of waste disposal facilities, population density, and environmental factors, researchers can identify patterns and trends that may impact the efficiency of waste disposal in Lugbe. GIS mapping can also help to identify areas that are underserved by waste disposal facilities, allowing for targeted interventions to improve waste management in these areas.

Spatial analysis techniques such as hotspot analysis, spatial autocorrelation, and cluster analysis can be used to identify spatial patterns and relationships in the data. These techniques can help researchers understand the spatial distribution of waste disposal facilities, identify areas of high waste generation, and assess the efficiency of waste disposal in different parts of Lugbe FCT.

It is important to engage with stakeholders such as local government officials, waste management companies, and community members throughout the research process. Involving stakeholders in the research, researchers can gain valuable insights into the challenges and opportunities for improving waste disposal facilities in Lugbe. Stakeholder engagement can also help to build support for proposed interventions and ensure that the research findings are relevant and actionable. Finally, waste management system should be established to enhance waste management in the area.

Compliance with ethical standards

Acknowledgments

The authors would like to deeply thank the staff of Strategic Space Applications (SSA) department in National Space Research and Development Agency (NASRDA), Abuja, and the staff of African Regional Centre for Space Science and Technology Education-English (ARCSSTE-E) Ile-Ife, Osun state, Nigeria for their immense contribution in making this work a reality.

Disclosure of conflict of interest

No conflict of interest is to be disclosed.

References

[1] Allan, Z. Assessment of Solid Waste Management in Residential Townships in Lusaka Zambia. *Acta scientific agriculture* 2019; 3 (11) 62-66.

[2] Jamila, I. H. Z. Assessment of Solid Waste Disposal System in Jimeta, Adamawa state, Nigeria. *British Journal of Environmental Sciences* 2018; 7 (1) pp. 43-52

[3] Akinwonmi, A.S.; Adzimah, S. K. & Karikari, C. M. Assessment of Solid Waste Management in Tarkwa Municipality Ghana: Time Series Approach. *Journal of Environment and Earth Science,* 2012; (2)10 139-147

[4] Njoku, N; Lamond, J.; Everett, G. and Manu, P. An Overview of Municipal Solid Waste Management in Developing and Developed Economies: Analysis of Practices and Contributions to Urban Flooding in Sub-Saharan Africa. In: 12th International Postgraduate Research Conference Proceedings, Manchester, UK, and 10-12 June 2015. pp. 200212 Available

[5] US EPA. Communicating the benefits of recycling. United State Environmental Protection Agency. Available at: www.epa.gov/osw/conserve/tools/localgov/benefits/index.htm_2011; [Accessed 17 August 2012]

[6] Fides K. K. and Edward H. W. Determination of Suitable Landfill Site Using Geospatial Techniques and Multi-Criteria Decision Analysis: A Case Study of Nakuru Town, Kenya, *International Journal of Science and Research (IJSR)* 2014; 3:11, 2319-7064.

[7] Aladejebi, O. J.; Adeyeye, A. J. & Olatunji, E. O. Assessment of Solid Waste Management in IFE North Local Government Area, Osun State, Nigeria. *International Journal of Scientific and Research Publications*, 2015; 5 (9) 1-8

[8] Levis, J.W.; Barlaz, M.A., & DeCarolis, J. F. A generalized multistage optimization modeling framework for life cycle assessment-based integrated solid waste management. *Environmental Modelling & Software* 2013; 50: 51–65.

[9] Moh, Y. C. & Abd-Manaf, L. Overview of household solid waste recycling policy status and challenges in Malaysia." Resources, Conservation and 76 Recycling 2014; 82:50-61. doi: 10.1016/j.resconrec.2013.11.004

[10] Yukalang, N, Clarke, B, Ross K. Solid Waste Management Solutions for a Rapidly Urbanizing Area in Thailand: Recommendations Based on Stakeholder Input. *Int. J. Environ. Res. Pub. Health.* 2018

[11] Hoornweg, D. and Bhada-Tata, P. What a Waste: A Global Review of Solid Wast Management. In: Urban development series, knowledge papers. Washington: World Bank; 2012

[12] World Bank. What a Waste. A Global Review of Solid Waste Management. Urban Development & Local Government Unit World Bank 1818 H Street, NW Washington, DC 20433USA 2012

[13] UNEP - United Nations Environment Programme. Global Waste Management Outlook. ISBN: 978-92-807-3479-9 DTI /1957/JA 2015

[14] Surendra, K. Y. GIS Based Approach for Site Selection in Waste Management. *International Journal of Environmental Engineering and Management*, 2013; 4 (5) pp. 507-514

[15] Emun GM. Multi criteria approach for suitable quarry site selection in Addis Ababa using remote sensing and GIS. Unpublished M.Sc. Thesis, Addis Ababa University, Ethiopia. *Environment & Earth Science* 2010; 14 (2)1-7

[16] Kamble, S. K.; Patil, K. and Pawar, U. C. GIS in Municipal Solid Waste Management. *International Journal of Scientific & Engineering Research*, 2019; 10 (5) 41-45

[17] Ebistu, T. A. and Minale, A. S. Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia. *African Journal of Environmental Science and Technology*, 2013; Vol. 7(11), pp. 976-989

[18] Shoba, B., and Rasappan, K. Application of GIS in solid waste management for Coimbatore City. *International Journal of scientific and Research Publications*, 2013; 3(10)

[19] Sule, J. O.; Aliyu, Y. A. and Umar, M. S. Application of GIS in Solid Waste Management in Chanchaga Local Government Area of Niger State, Nigeria. *Journal of Environmental Science, Toxicology and Food Technology,* 2014; 8 (9) PP 17-21

[20] World Bank Group. (). Solid Waste Management. Retrieved from http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management. 2019

[21] Abur, B. T.; Oguche, E. E. & Duvuna, G. A. Characterization of Municipal Solid Waste in the Federal Capital Abuja, Nigeria*. Global Journal of Science Frontier Research: H.* 2014

[22] Singh, J.; Lauren, R.; Sinha, R. and Frostell, B. Progress and challenges to the global waste management system. *Waste Management & Res.* 2014; 32(9):800 –812

[23] Fasil, K. D.; Zelalem, K.; Zeberihe, E.; Bizuhayew, A.; Daba, L.; Tesfaye, G.; Tesfaye, W. and Urgessa, M. Assessment of Solid Waste Management Trends of Bishoftu Households Community, Ethiopia. *International Journal of Environmental Sciences & Natural Resources* 2019; 21(3) 98-110.

[24] Tijani, M. N. Geology of Nigeria Precambrian Basement Complex Sedimentary Rocks Cretaceous Quaternary Alluvial deposit. *ResearchGate*. https://www.researchgate.net/publication/374696133_Geology_of_Nigeria_Precambrian_Basement_complex_Sedimentary_rocks_Cretaceous_Quaternary_Alluvial_deposit. 2023

[25] Harman, G., & Kulkarni, S. Statistical Learning Theory as a framework for the philosophy of induction. In *Elsevier eBooks* 2011 (pp. 833–847). https://doi.org/10.1016/b978-0-444-51862-0.50027-7

[26] Martin, O. A. Governance Crisis or Attitudinal Challenges? Generation, Collection, Storage and Transportation of Solid Waste in Ghana. Integrated Waste Management. In Tech 2011; 1, (978- 953-307-469-6)

[27] Arvind, K, J., Singh, S. K. and Probhat, K, G. Sustainable municipal Solid Waste Management in low-income group of cities: a review. *Journal Tropical Ecology* 2011; 52(1): 123-131

[28] Ikhuoso, O.A. The Role of Educational Programs to Enhance Stakeholder Participation for Sustainable Waste Management in Developing Countries: An Investigation into Public Secondary Schools in Nigeria. Int J Waste Resour 2018; 8: 350. doi: 10.4172/2252-5211.1000350

[29] Hashimoto, Y. Waste Management in Urban India and role of social Enterprises. Eurasian *Journal of Business and Management* 2016; 4 (1), 10