

Solid Waste Glitches: Geospatial Distribution of Open Waste Dumpsites in Nsukka Urban, Enugu State, Nigeria

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Abstract

Solid waste is inevitable, but the bone of contention is poor management, occasioned by swift population increase, urbanization, and development, multiplying waste volume in society. Therefore, the study explored the geospatial distribution of solid waste dumpsites in Nsukka Urban, Enugu state. Leveraging the Theory of Planned Behavior (TPB) and Community-Based Participatory Research (CBPR), this research investigates the socio-environmental dynamics and community engagement related to waste management practices. Using Global Positioning System (GPS) waypoints and QGIS (Quantum Geographic Information System) software, version 3.40.1, a total of 57 waste disposal sites were identified (33.3% authorized and 61.4% unauthorized sites), with a high concentration in the northeastern part. Interviews with local waste disposal workers and residents were conducted to identify, gather, and analyze data on waste disposal practices and concentration at the dumpsites. The spatial analysis explored using Nearest Neighbor Analysis (NNA) revealed a clustered pattern of open waste disposal sites ($R_n = 0.47$). There were clear signs of poor waste management, including littered waste and delays in waste evacuation. Factors influencing indiscriminate waste disposal include the distance of dumpsters, inadequate sanitation facilities, non-compliance with waste evacuation monthly payments, inconsistency in sanitation dues collection, and inadequate funding. The study recommends placing additional dumpsters in areas lacking them and using Geographic Information Systems in planning to enhance sustainable waste management practices.

Introduction

Sustainable waste management efforts are made much more arduous by the global increase in waste generation (Mor and Ravindra, 2023). This is because, as population is increasing, the quantity of waste produced on daily bases has upsurged exponentially. The global average waste production is 0.74 kg/Cap/day, with rates varying across countries (Mor and Ravindra, 2023). **Due to rising urbanization and increasing population, the world's yearly waste generation is expected to total 3.40 billion tonnes by 2050 (Omotayo, 2024).** In most African cities, solid waste management presents a formidable challenge. Up to 90% of waste is openly dumped and often burned, producing harmful substances that impact public health and the environment (Mebratu, 2022).

Urban areas are proliferating, with the highest annual increase rate globally at 3.5%, yet waste management infrastructure, particularly in slums and rural areas, is not keeping pace (UNICA, 2009). less than half of solid waste are collected and 95% are disposed indiscriminately at dumping sites (Hoornweg and Bhada-Tata, 2018). The increasing use of ICT and technology, particularly computers and mobile phones, is leading to a significant e-waste stream in Africa, resulting in no waste management capacity and causing both municipal and e-waste to be disposed of at dump sites (UNECA, 2009).

Solid waste disposal sites, often located on the outskirts of urban areas, are home to flies, mosquitoes, and rodents, which become child sources of contamination because of their incubation and growth. These organisms spread disease that impact the population's health, which has its natural defenses in a

formative and creative state (Abul, 2010). The pollution caused by waste from street vendors is particularly evident in the central business districts of cities in developing nations (Grangxabe et al., 2024). Despite significant waste recycling potential, only a small fraction is processed, with informal waste pickers playing a major role in resource recovery from these sites (Li et al., 2022; Hidalgo-Crespo et al., 2023).

In Nigeria, municipal solid waste is primarily disposed of through open spaces, waterways, or burn piles due to insufficient waste collection coverage and limited access to centralized facilities (Ezeah and Roberts, 2014; Nnaji et al., 2020; Inem et al., 2021). Nigeria's waste management is poor and difficult throughout the process (Nwosu and Chukwueloka, 2020). Nigeria generates daily solid waste of 0.43-0.66 kg/capital/day and annually over 32 million tons, with only a fraction collected particularly from households, local industries, artisans, and traders (Orhorhoro and Oghoghorie 2019; Bakare, 2020).

Illegal waste dumpsites in Nigerian cities are a result of a feeble waste management system, causing aesthetic loss, environmental harm, disease spread, and pollution (Nnaji, 2015; Momodu et al., 2011). Improper waste collection for final disposal result in health issues like typhoid fever, cholera, dysentery, skin disease, malaria, hepatitis, and guinea horn disease, and can also cause epidemic outbreaks (Bassey et al., 2006). Current cholera outbreak in Nigeria is a good example as at least 1528 suspected cases and 53 casualties was reported between January to June 24, 2024, within 30 states in Nigeria, according to the Nigeria Centre for Disease Control and Prevention (NCDC) (Nigeria Health Watch, 2024). The disposal of solid waste in Nigeria has been a protracted issue. However, the application of GIS and Remote Sensing Technologies has significantly enhanced the modalities to spatially identify the best locations for waste disposal sites, expediting the planning process and reducing operational costs(Onuigbo and Bello, 2014, Kaoje et al., 2016).

In Enugu state, Onyishi et al. (2023) revealed significant deficiencies in waste management in Enugu Metropolis, including inadequate collection, transfer, separation, and disposal, and minimal recycling efforts. Nsukka urban in Enugu State has witnessed rapid population and economic growth over the last two decades (Eze, 2021). This has increased the generation of heterogeneous solid wastes dumped in open spaces across the city due to lack of efficient waste collection and disposal infrastructure (Ugwu, 2018). The Enugu State Waste Management Authority (ESWAMA) in Nsukka, struggles to manage the large volume of waste generated, and despites the concerted efforts of the agency, the challenges appear unabated (Nwosu et al., 2017; Nnaji, 2015). As of 2012, only one of the two collection trucks was functional (Nnaji et al., 2021). The inability to handle the volume of waste has led to delays in evacuating waste at temporary dumpsites.

Numerous studies on waste management practices in Nigeria, including Nsukka abound in literature (Popoola et al., 2016; Ugwu and Echiegu, 2018; Nnaji et al., 2020). However, the spatial dimension of open dumpsites in Nsukka urban is limited in literature, which aroused the interest for this study. The study examined the geospatial distribution of open waste dumpsites in Nsukka urban. The study aims to identify authorized and unauthorized waste dumpsites, analyse spatial waste disposal patterns, and

pinpoint areas with the highest concentration of open dumpsites. Leveraging on the Theory of Planned Behavior (TPB) and Community-Based Participatory Research (CBPR), this research investigates the socio-environmental dynamics and community engagement related to waste management practices. Understanding geospatial factors associated with existing dumpsites through GIS, leveraging on these theories could expedite identification of alternative safer disposal options for sustainable waste management (Asafa, 2022). This study is crucial and apt as it provides practical insights to develop comprehensive strategies to addressing the complex issues of open waste disposal in the Nsukka urban.

The Research Hypothesis

1. There is no significant difference between the distribution (or pattern) of open waste dump sites and a random distribution (pattern) in Nsukka urban.

1.7.1 Overview of the Study Area

The research area is Nsukka Urban, located in southeast Nigeria between 06° 18' and 07° 06' north and 06° 52' and 07° 54' east (Ezeide et al., 2017). As an urban area, it is bordered to the north by Eden, ObolloAfor, and Opi (an archaeological site) (Okereke et al., 2022). Its population is 309,633, comprising 149,241 males and 160,392 females (NPC, 2006, Nnaji et al., 2021). It has an average temperature of about 27°C (80°F) and a typical vegetation of rain forest (Nnaji et al., 2021). The study area is home to the main campus of the University of Nigeria, being the first indigenous university in the country, founded by the late Dr. Nnamdi Azikiwe in 1960 (Okereke et al., 2022), primarily inhabited by civil servants, students, traders, and farmers (Nnaji et al., 2021).

The problem of solid waste management is a critical concern in Nsukka (Nnaji et al., 2021). Households commonly use various types of waste containers, including plastic, polythene bags, cartons, metal containers, and drums (Nnaji et al., 2021). However, inadequate waste services and disposal facilities lead to issues like open dumping in urban areas like Nsukka Urban in Nigeria. Onyeka (2011) emphasized the widespread issue of uncoordinated street refuse dumping, which poses environmental threats to building facilities and public health in Nsukka. The current state of solid waste management in Nsukka urban is worrisome as wastes are seen dumped at the heart of the town. Map of Enugu showing the study area and map of Nsukka urban are in figure 1 and 2.

2.2 Theoretical Concept

This study employs the Theory of Planned Behavior (TPB) and Community-Based Participatory Research (CBPR) to holistically examine and address the spatial and social dynamics of waste disposal in Nsukka urban

2.2.1. The Theory of Planned Behavior (TPB)

The Theory of Planned Behavior (TPB), proposed by Ajzen (1991), offers a comprehensive framework for understanding human behavior, particularly in the context of waste disposal. According to TPB, an individual's behavior is influenced by their intention to perform the behavior, which, in turn, is shaped by three main factors: attitude towards the behavior, subjective norms, and perceived behavioral control.

- Attitude towards the behavior encompasses the individual's positive or negative evaluation of the behavior. It extends to one's belief on something. In the context of waste disposal, attitudes may include perceptions of the environmental impact of open waste disposal, concerns about health risks associated with improper waste management, and considerations related to the aesthetics of waste disposal sites (Ajzen, 1991).
- Subjective norms refer to the perceived social pressures to perform or not perform the behavior. For waste disposal, subjective norms could include the influence of family, friends, and community members who may approve or disapprove of open waste disposal practices. These social pressures can significantly impact an individual's intention to engage in proper waste disposal practices (Ajzen, 1991).
- Perceived behavioral control relates to the individual's perceived ease or difficulty in performing the behavior. Factors such as access to waste disposal facilities, knowledge about proper waste disposal methods, and the availability of alternative disposal options can influence perceived behavioral control. Individuals who perceive waste disposal to be within their control are more likely to engage in proper disposal practices (Ajzen, 1991).

Community-Based Participatory Research (CBPR)

Community-Based Participatory Research is a collaborative approach to research that involves community members throughout the research process. It emphasizes the importance of involving community stakeholders as equals in the research process to ensure that the outcomes are relevant and beneficial for the community. Integrating the Community-Based Participatory Research (CBPR) approach, this framework ensures that the research process is inclusive and collaborative, engaging community members as active partners. CBPR enhances the application of TPB by ensuring that community insights and perspectives inform the identification, mapping, and analysis of waste disposal sites. This approach not only enriches the data with local knowledge but also fosters community empowerment by involving them in the research process, thereby increasing the likelihood of sustainable outcomes (Israel et al., 1998). By integrating the Theory of Planned Behavior (TPB) and Community-Based Participatory Research (CBPR) into the conceptual framework, this study aims to comprehensively understand the spatial and social dynamics of waste disposal in Nsukka urban. This approach facilitates the development of targeted interventions that are effective and rooted in the needs and realities of the community. By ensuring that the study's findings and recommendations are practically applicable, this integrated approach contributes to improved environmental health and enhanced community well-being in urban landscapes

Methodology

3.1 Study Design

The study employed a combination of Geographic Information Systems (GIS), Global Positioning System (GPS) waypoints, and interviews to gather and analyze data on waste disposal practices and dumpsites within Usukka urban. Leveraging on the Theory of Planned Behavior (TPB) and Community-Based Participatory Research (CBPR), this research investigates the socio-environmental dynamics and community engagement related to waste management practices.

Method of Data Collection

A combination of secondary and primary data was employed. The secondary data include data from books, journal articles, map, newspapers and other internet documents. The primary data were gathered through observation and interview with waste disposal workers and Nsukka residents. The essence was to gather firsthand information into the operational aspects and societal impacts of waste disposal sites in Nsukka Urban. Geographical coordinates of various open waste disposal dumpsites were recorded using the GPS Waypoint app. This method ensured precise location tracking of each site within Nsukka Urban. Simultaneously, photographs of these sites were taken to show at a glance the physical conditions and surroundings of the dumpsites.

Data Analysis

Coordinates gathered from the field were imputed into an Excel spreadsheet as preliminary data, which included critical details such as legality, precise coordinates, and descriptions of the locations. This dataset was then converted into a comma-separated values (CSV) file format to facilitate further processing with QGIS (Quantum Geographic Information System) software (Flenniken et al., 2020). Once imported into QGIS, the data in CSV format was transformed into a shapefile for detailed spatial analysis. The digital base map of Nsukka Urban, sourced and digitized from satellite imagery based on OpenStreetMap (OSM) standards, was used within QGIS. Spatial analyses were performed, involving creating a distance matrix to evaluate the proximity between sites and employing the area measurement tool to determine the total square kilometres of the study area. Nearest Neighbour Analysis (NNA) was adopted to evaluate the spatial distribution(pattern) of dumpsites in Nsukka Urban. The formula for NNA is:

$$R_n = 2(D) * \sqrt{N/A},$$

where:

R_n represents the Nearest Neighbour Index

D is the mean distance between the nearest dump sites in square kilometres,

N is the number of points (dump sites),

A is the study area.

According to ESRI, If the index (average nearest neighbor ratio) is less than 1, the pattern exhibits clustering. and if the index is greater than 1, the trend is toward dispersion. Therefore

- $R_n > 1$: If the index is greater than 1, it suggests a dispersed pattern. This means dumpsites are spaced out more than if they were randomly placed.
- $R_n = 1$: An index of exactly 1 indicates a random distribution — the dumpsites are neither clustered nor evenly spread out.
- $R_n < 1$: If the index is less than 1, it implies a clustered pattern. Dumpsites are grouped closer together than one would expect in a random distribution

This statistical approach was used to address the stated hypothesis. Two separate maps were produced to present the overall and legal/illegal distributions of waste dumps in Nsukka Urban. Additionally, a heatmap was generated to visualize and pinpoint areas with high concentrations of dumpsites.

Results and Discussion

Classifications of Waste Disposal Sites

A total of 57 waste disposal sites was identified across Nsukka Urban (Table 1). Of these, 19 are authorized sites officially recognized and regulated by Enugu State Waste Management Authority (ESWAMA), Nsukka branch, while 38 are unauthorized, indicating a significant challenge in managing urban waste effectively as the unauthorized are more in number than approved sites. The unauthorized sites are initiated by the residents who took advantage of undeveloped land and open spaces close to the road. Most of the illegal dumpsites are very close to residential houses and people staying in such locations may be prone to malarial, cholera and mosquitoes. The coordinates, status and locations of these dumpsites are included in Table 1.

Table 1: Classification of Solid Waste Disposal Sites in Nsukka Urban

DUMPSITES	LATITUDE	LONGITUDE	STATUS	LOCATION
1	6°51'21.36"	7°23'42.59"	ILLEGAL	UNIVERSITY RD1
2	6°50'52.07"	7°23'44.62"	LEGAL	AKU RD
3	6°50'28.74"	7°24'9.43"	LEGAL	ECHARA RD
4	6°51'16.21"	7°24'12.71"	ILLEGAL	MOUKA RD2
5	6°51'22.12"	7°24'18.71"	ILLEGAL	ODENIGWE 1
6	6°51'16.13"	7°24'16.78"	ILLEGAL	ODENIGWE RD 2
7	6°51'13.34"	7°24'39.38"	ILLEGAL	HIL TOP RD 1
8	6°51'12.31"	7°24'46.32"	ILLEGAL	HIL TOP RD 2
9	6°51'31.13"	7°24'41.95"	ILLEGAL	HIL TOP FENCE 1
10	6°51'33.87"	7°24'42.49"	ILLEGAL	HIL TOP FENCE 2
11	6°51'37.80"	7°24'43.34"	LEGAL	AKINTOLA HOSTEL UNN
12	6°51'47.98"	7°24'49.01"	LEGAL	BESIDE STUDENT AFFAIRS UNN
13	6°51'54.56"	7°24'44.16"	ILLEGAL	VERTERNARY DEPARTMENT UNN
14	6°52'0.37"	7°24'38.20"	ILLEGAL	BESIDE ABUJA BULDING UNN
15	6°51'52.43"	7°24'26.60"	LEGAL	CONTAINER UNN
16	6°51'43.75"	7°24'36.79"	LEGAL	BESIDE EKPO REF UNN
17	6°51'43.85"	7°24'17.30"	LEGAL	GS BUILDING UNN
18	6°51'39.11"	7°24'30.38"	LEGAL	GEOGRAPHY DEP. UNN
19	6°50'25.78"	7°23'28.23"	LEGAL	TECTANUS RD
20	6°52'06.14"	7°24'11.52"	ILLEGAL	ENI NJOKU HOSTEL UNN
21	6°51'18.91"	7°23'34.74"	LEGAL	PRISON RD
22	6°51'25.05"	7°23'56.53"	LEGAL	UNN MARKET RD
23	6°50'52.03"	7°23'53.90"	ILLEGAL	BEHIND PEACE PARK
24	6°51'18.29"	7°24'8.08"	ILLEGAL	MOUKA RD1
25	6°51'20.40"	7°23'0.44"	LEGAL	NSK-ONITSHA RD1
26	6°51'37.42"	7°23'8.93"	ILLEGAL	NSK-ONITSHA RD2
27	6°50'56.05"	7°23'18.83"	ILLEGAL	BESIDE ST TERESE RD
28	6°52'21.19"	7°24'31.52"	ILLEGAL	ODIM RD 1 UNN

29	6°52'18.74"	7°24'31.43"	ILLEGAL	ODIM RD 2 UNN
30	6°52'11.08"	7°24'31.59"	ILLEGAL	ODIM RD 3 UNN
31	6°52'9.15"	7°24'31.11"	ILLEGAL	ODIM RD 4 UNN
32	6°50'50.57"	7°23'18.64"	LEGAL	NEW ANGLICAN RD
33	6°51'24.26"	7°24'37.33"	ILLEGAL	HITOP RD 3
34	6°50'52.95"	7°24'6.68"	ILLEGAL	ORBA RD 1
35	6°50'13.72"	7°22'12.41"	LEGAL	IKENGA JUCTION
36	6°50'40.77"	7°21'53.09"	ILLEGAL	IBEGWA ANI RD
37	6°50'47.76"	7°22'24.26"	ILLEGAL	AGU EHERA PR SCHOOL
38	6°50'33.96"	7°24'23.29"	LEGAL	UMUCHE RD
39	6°49'50.52"	7°24'26.50"	ILLEGAL	AMULA RD (ENUGU RD)
40	6°51'50.81"	7°23'18.14"	ILLEGAL	OBOLO IDAH RD
41	6°52'22.86"	7°23'58.08"	LEGAL	BEHIND FLAT JOINT
42	6°51'50.68"	7°23'45.47"	ILLEGAL	UNN RD
43	6°52'44.61"	7°24'19.82"	LEGAL	NKPUR JUNCTION
44	6°52'38.99"	7°23'58.80"	ILLEGAL	ONUHI RD
45	6°49'42.19"	7°24'25.05"	ILLEGAL	ENUGU RD 1
46	6°50'20.10"	7°21'58.24	ILLEGAL	NIBO RD
47	6°52'12.05"	7°24'6.00"	ILLEGAL	UNN BOYS HOSTEL
48	6°50'42.42	7°21'42.60"	ILLEGAL	IBEGWA ANI RD 2
49	6°52'6.80"	7°23'10.64"	ILLEGAL	OBOLO-IDAH RD1
50	6°52'10.12"	7°23'10.98"	ILLEGAL	OBOLO-IDAH RD2
51	6°52'10.12"	7°23'58.87"	ILLEGAL	OBUKPA RD1
52	6°52'56.83"	7°23'54.17"	ILLEGAL	OBUKPA RD2
53	6°50'57.51	7°25'43.59"	ILLEGAL	UNN GATE 3
54	6°50'58.35"	7°23'36.67"	LEGAL	BISHOP SHANAHAN HOSPITAL
55	6°52'39.04"	7°24'30.02"	ILLEGAL	BESIDE EJUONA PR SCH
56	6°52'9.20"	7°23'54.52"	LEGAL	UNN GATE 2
57	6°52'9.64"	7°23'59.97"	ILLEGAL	UNN PG HOSTEL

Spatial Distribution of Solid Waste Dump Sites

The spatial distribution of waste dumpsites is in Figures 3 and 4. The entire waste dumpsites are indicated with purple points (fig. 3), while the authorised and unauthorised dumpsites are marked with green and red colours, respectively (fig. 4). The dumpsites were found more in the north-eastern part of Nsukka urban, probably in accordance with the general trend of urbanization and where population was higher. As long as people live there, waste will inevitably be produced, but abuse of it is the bone of contention. By implication, areas with a higher density of dumpsites are likely to have higher trash volumes, and their inhabitants are likely to have greater issues connected to poor waste management. For example, compared to other communities, the "Ihe" and "Owerri Nsukka" communities with the most dumpsites may suffer more, especially if these dumps are not cleared promptly. Consequently, a spatial database that visually represents the distribution and status of waste disposal sites for sustainable planning and development is paramount.

Statistical Analyzing of the Distribution (Pattern) of Waste Dump Sites

To ascertain the spatial arrangement of waste dumpsites across Nsukka Urban, a Nearest Neighbour Analysis (NNA) was conducted. This statistical approach was employed to address hypothesis 1 that states that "there is no significant difference in the distribution of open waste dumpsites across the Nsukka urban area." The formula used is:

$$R_n = 2(D) * \sqrt{N/A}.$$

Where:

R_n represents the Nearest Neighbor Index

D is the mean distance between nearest dump sites in square kilometers,

N is the number of points (dump sites),

A is the area of the study in square kilometers.

Determination of Average Distance (D): Distance of each dumpsite to the nearest dumpsite are shown in table 2.

Table 2: The Proximity of Each Waste Disposal Site to its Closest Neighbor

S//N	DUMPSITES	DUMPSITES	DISTANCE (KM)
1	UNIVERSITY ROAD 1	PRISON ROAD	0.25
2	AKU ROAD	BEHIND PEACE PARK	0.28
3	ECHARA RD	UMUCHE ROAD	0.45
4	MOUKA ROAD 2	ODENIGWE ROAD 2	0.12
5	ODENIGWE 1	ODENIGWE ROAD 2	0.19
6	ODENIGWE ROAD 2	MOUKA ROAD 2	0.12
7	HIL TOP ROAD 1	HIL TOP ROAD 2	0.22
8	HIL TOP ROAD 2	HIL TOP ROAD 1	0.22
9	HIL TOP FENCE 1	HIL TOP FENCE 2	0.09
10	HIL TOP FENCE 2	HIL TOP FENCE 1	0.09
11	AKINTOLA HOSTEL UNN	HIL TOP FENCE 2	0.12
12	BESIDE STUDENT AFFAIRS UNN	VERTERNARY DEPARTMENT UNN	0.25
13	VERTERNARY DEPARTMENT UNN	BESIDE STUDENT AFFAIRS UNN	0.25
14	BESIDE ABUJA BULDING UNN	VERTERNARY DEPARTMENT UNN	0.26
15	CONTAINER UNN	GS BUILDING UNN	0.39
16	BESIDE EKPO REF UNN	GEOGRAPHY DEP UNN	0.24
17	GS BUILDING UNN	CONTAINER UNN	0.39
18	GEOGRAPHY DEP UNN	BESIDE EKPO REF UNN	0.24
19	TECTANUS ROAD	NEW AGLICAN ROAD	0.82
20	ENI NJOKU HOSTEL UNN	UNN BOYS HOSTEL	0.25
21	PRISON RD	UNIVERSITY ROAD 1	0.25
22	UNN MARKET RD	MOUKA ROAD 1	0.41
23	BEHIND PEACE PARK	AKU ROAD	0.28
24	MOUKA ROAD 1	MOUKA RD2	0.16
25	NSK-ONITSHA ROAD 1	NSK-ONITSHA ROAD 2	0.58
26	NSK-ONITSHA ROAD 2	OBOLO IDAH ROAD	0.50
27	BESIDE ST TERESE ROAD	NEW AGLICAN ROAD	0.17
28	ODIM ROAD 1 UNN	ODIM ROAD 2 UNN	0.08

29	ODIM RD 2 UNN	ODIM ROAD 1 UNN	0.08
30	ODIM ROAD 3 UNN	ODIM ROAD 4 UNN	0.06
31	ODIM ROAD 4 UNN	ODIM ROAD 3 UNN	0.06
32	NEW AGLICSN ROAD	BESIDE ST TERESE ROAD	0.17
33	HITOP ROAD 3	HIL TOP FENCE 1	0.25
34	ORBA ROAD 1	BEHIND PEACE PARK	0.39
35	IKENGA JUNCTION	NIBO ROAD	0.48
36	IBEGWA ANI ROAD	IBEGWA ANI ROAD 2	0.33
37	AGU EHERA PR SCHOOL	IBEGWA ANI ROAD	0.98
38	UMUCHE ROAD	ECHARA ROAD	0.45
39	AMULA RD (ENUGU ROAD)	ENUGU ROAD 1	0.26
40	OBOLO IDAH ROAD	NSK-ONITSHA ROAD 2	0.50
41	BEHIND FLAT JOINT	OBUKPA ROAD 1	0.39
42	UNN ROAD	UNN GATE 2	0.63
43	NKPUR JUNCTION	BESIDE EJUONA PR SCH	0.36
44	ONUHI ROAD	BEHIND FLAT JOINT	0.50
45	ENUGU ROAD 1	AMULA ROAD (ENUGU ROAD)	0.26
46	NIBO ROAD	IKENGA JUNCTION	0.48
47	UNN BOYS HOSTEL	PG HOSTEL	0.20
48	IBEGWA ANI ROAD 2	IBEGWA ANI ROAD	0.33
49	OBOLO-IDAH ROAD 1	OBOLO-IDAH RD2	0.10
50	OBOLO-IDAH RD2	OBOLO-IDAH RD1	0.10
51	OBUKPA ROAD 1	PG HOSTEL	0.04
52	OBUKPA ROAD 2	ONUHI ROAD	0.57
53	UNN GATE 3	HIL TOP ROAD 2	1.82
54	BISHOP SHANAHAN H	AKU ROAD	0.31
55	BESIDE EJUONA PR SCH	NKPUR JUNCTION	0.36
56	UNN GATE 2	OBUKPA ROAD 1	0.14
57	PG HOSTEL	OBUKPA ROAD 1	0.04

	SUM = 18.30
	MEAN = 0.3

The average nearest neighbor distance was calculated to be 0.3 kilometers. This measurement shows the average proximity of each waste disposal site to its closest neighbor.

Number of Waste Disposal Sites (N): A total of 57 dumpsites were identified, including authorized and unauthorized.

Extent of the Study Area (A): The spatial extent covered was 92 square kilometers of urban space, setting the boundaries for the NNA.

Substituting the values:

$$R_n = 2 * 0.3 * \sqrt{57/92}$$

$$R_n = 0.6 * \sqrt{0.61}$$

$$R_n = 0.6 * 0.78$$

$$R_n = 0.47$$

Since R_n of 0.47 is approximately 0.5, the pattern of waste dump sites indicates a clustered pattern. The NNA of 0.5, is significantly below 1, meaning that the waste disposal sites within Nsukka Urban are not randomly or uniformly distributed but are clustered which could informed reasons why most residents discard wastes indiscriminately. From observation, most of the waste dumps are concentrated in the northeastern part. This clustering pattern could be the influence of accessibility/proximity, urbanizing nature of the region and the high population density in the northern parts of the area.

4.4: Concentration of Solid Waste Dumpsites

Figure 5 shows the intensity and hotspots where waste dump sites are highly concentrated. The areas, depicted with intense coloration on the heatmap, represents critical hotspot zones where waste heaps are higher. This could be linked to the urbanizing nature of these areas and the high population density, particularly in the northeastern part of Nsukka urban. Location with highest concentration of waste dumps is Ihe Nsukka, followed by Owere Nsukka. Since bulk of the dump sites are in these locations, the residents might equally be bearing much impacts from these dump sites which are inimical to human health compare to other locations and these could affect the socioeconomic life of the residents. Despite the high demand for accommodation in Nsukka urban, most people prefer eco-friendly environment irrespective of the price of rentage. While some due to poverty, opt to location where accommodation is affordable, and bear waste impacts, and probably spending more on drugs and hospital bills unwittingly. Sustainable waste management practices could prevent environmental

degradation and illnesses, ensuring the safety of residents and reducing the impact of poor waste manage

From observation, many of these sites are sited alarmingly close to residential areas, where the proximity of waste accumulation leads to direct exposure to health hazards for the inhabitants. The presence of waste in such close quarters to homes not only facilitates the spread of disease vectors such as rodents and insects but also contributes to air and water pollution that could affect broader ecological systems. Moreover, a recurring issue noted was the obstruction of drainage channels by improperly disposed waste. This mismanagement exacerbates flooding risks during the rainy season, leading to potential property damage and increasing the risk of waterborne diseases. Some heaps of wastes were burned openly, further diminishes the aesthetic value of the community and negatively impacting the life of residents. The compelling photographs of these waste dump sites depicting the conditions of the examined sites are in plate 1 to 3.

These images depict waste heaps alongside the routine activities of the community, highlighting the urgency for addressing waste management as a critical component of urban planning.

Interviews conducted with local waste management officials and residents shed light on the operational challenges and societal impacts of current waste practices. Waste management personnel reported issues such as inadequate resources for proper waste processing and irregular service schedules, which hinder effective management. Furthermore, most residents do not comply to their monthly financial obligation towards sanitation. From the community perspective, residents expressed concerns over health issues arising from the proximity of dumpsites to their homes. They lamented on unpleasant odor and an increase in pest-related problems, which they directly attributed to waste at dumpsites. Feedback from these interviews suggests a sensitive lapse between the waste management services provided and the needs of the community. This gap underscores the necessity for a participatory approach in waste management planning that includes community feedback to ensure that services meet local needs for sustainable waste management.

Conclusion

The geospatial analysis of waste disposal sites in Nsukka Urban, Enugu State, Nigeria was examined. The study revealed a significant concentration of both authorized and unauthorized dumpsites. The unauthorized dumpsites (67%) were more than the authorized dumpsites (33%). Arbitrary dumping of wastes by the residents is occasioned by some factors like inadequate dumpsters, far distances of officially approved dump sites and unwillingness of some who do not want to stress themselves to those legal waste dumpsites.

The findings show a pronounced clustered waste disposal sites, particularly in the northeastern parts of the urban area, which are heavily influenced by urbanization and high population density. Since the Nearest Neighbor Analysis is less than 1 ($R_N = 0.47$), the distribution (pattern) of dumpsites is clustered. This spatial clustering is indicative of systemic inefficiencies in waste management

infrastructure and highlights areas where intervention is critically needed. Indiscriminate disposal of wastes and poor management of dumpsites poses serious environmental and public health risks. These risks include the spread of disease through vectors such as rodents and insects, and the contamination of air and water resources, which significantly impacts the well-being of the people in Nsukka urban. The study highlights the negative impact of waste on the community, emphasizing the need for comprehensive waste management strategies. The integration of spatial data with community insights has provided a robust foundation for understanding the challenges and dynamics of waste management in Nsukka Urban. It is evident that the current waste management practices are insufficient to meet the needs of the growing urban population and do not comply with sustainable waste management practices. Consequently, the study therefore suggests the following:

Additional dumpsters should be prioritized and strategically placed to shorten the commute to disposal locations. The government should establish modern landfill sites and waste recycling centres, utilizing recycling opportunities to reduce waste, engage youth, and generate income. Waste management laws and regulations should be strictly enforced to discourage indiscriminate dumping. Awareness campaign is essential to educate the public on the health and environmental risks of improper waste disposal. Utilizing Geographic Information Systems (GIS) and other spatial tools to continuously update the database of waste disposal sites and monitor changes in waste patterns will support effective management. By adopting these recommendations, Nsukka urban can move towards sustainable waste management practices that enhance life and environmental quality.

Declarations

Ethics Approval:

The study received approval from the Directorate of Strategic Contacts, Ethics and Publications (STRACEP) at the University of Nigeria, Nsukka (UNN) and it complied with the ethical guidelines established by the University. All authors have read, understood and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

Consent to participate:

The authors confirm they sought and got the consent from all participants in the study.

Consent for publication:

All named authors in the paper have agreed that the manuscript be submitted for publication.

Competing interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Clinical trial number

Not applicable

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Author Contribution

Matthew Ogorchukwu Isimah : Conceptualization, method, analysis, writing- Original draft and editing. Gladys Ogochukwu Chukwurah : Literature review, method, analysis and editing. Happy Agholor : Data analysis and final editing. Onyinyechi Gift Ossai : reviewing, and editing. Godwin Chukwudi Asogwa: Literature review , method and discussion of analytical results.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials, available at the behest of the first author.

References

Abubakar I.R, Maniruzzaman K.M., Dano U.L., AlShihri F.S., AlShammari M.S., Ahmed S.M.S. Al-Gehlani W.A.G. and Alrawaf T.I. (2022). Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. *Int J Environ Res Public Health*. 2022 Oct 5;19(19):12717. doi:10.3390/ijerph191912717.

Abul S. (2010). Environmental and health impact of solid waste disposal at management dumpsite in manzini: swaziland. *Journal of Sustainable Development in Africa* Volume 12, No.7.

Adeolu A. T., Enesi D. O., and Adeolu M. O. (2021). Review on the impact of urban solid waste management on the environment in Nigeria. *Environmental Science and Pollution Research*, 28, 12345-12356.

Africa Review Report on Waste Management - Main Report. (2009). Economic Commission for Africa (ECA). <https://www.uneca.org/publications>

Africa Waste Management Summary for Decision-Makers. (2022). UN Environment Document Repository Home. <https://wedocs.unep.org>

Agbo M. (2017). The problem with solid waste management in Nigeria's low-income neighborhoods. <https://earth.org/the-problem-with-solid-waste-management-in-nigerias-low-income-neighborhoods/>

Aja O. C., and Al-Kayiem, H. H. (2019). Review of municipal solid waste management options in Malaysia, with an emphasis on sustainable waste. <https://link.springer.com/article/10.1007/s10163-013-0220-z>

Ajzen I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211.

Akporido S. O., and Igbinomwanhia D. I. (2022). Challenges and prospects of solid waste management in Nigerian cities: A review. *Journal of Environmental Management*, 300, 113728.

Aneseyee A. B., Noszczyk T., Soromessa T., and Elias E. (2020). The invest habitat quality model associated with land use/cover changes: A qualitative case study of the Winike watershed in the Omo-Gibe basin, Southwest Ethiopia. *Remote Sensing*, 12(7), 1103.

Anyanwu N. C., and Adefila J. O. (2017). Nature and Management of Solid Waste in Karu Nasarawa State, Nigeria. *American International journal of contemporary Research*, volume 4(11).

Bassey B, Benka-Coker M and Aluyi H. S. (2006). Characterization and management of solid medical wastes in the Federal Capital Territory, Abuja Nigeria *Afr. Health Sci.* 6(1) 58 – 63

Braimah E. (2023). The current state of waste management in Nigeria and the challenges of transitioning to a circular economy. LinkedIn. <https://www.linkedin.com/pulse/current-state-waste-management-nigeria-challenges-circular-braimah>

Britannica, T. Editors of Encyclopedia (2024, February 9). Enugu. Encyclopedia Britannica. <https://www.britannica.com/place/Enugu-Nigeria>

Butu A. W and Mshelia S.S. (2014). Municipal solid waste disposal and environmental issues in Kano metropolis, Nigeria. *British Journal of Environmental Sciences*; Vol.2, No.1, pp.1-16.

Danbuzu L.A.S., Tanko A., Uzma I. and Mohammed A. (2014). Spatial Distribution of Solid Waste Collection Points Using GIS Approach in Urban Katsina, Katsina State, Nigeria. *American Journal of Engineering Research*. 3. 107-116.

Debrah J.K., Vidal D.G. and Dinis, M.A.P. (2021). Raising Awareness on Solid Waste Management through Formal Education for Sustainability: A Developing Countries Evidence Review. *Recycling*, 6, 6. <https://doi.org/10.3390/recycling6010006>.

Debrah J.K. Teye G.K. and Dinis M.A.P.(2022). Barriers and challenges to waste management hindering the circular economy in Sub-Saharan Africa Urban Science, 6 (3), p. 57.<https://doi.org/10.3390/urbansci6030057>

Demirbas A (2011) Waste management, waste resource facilities and waste conversion *processes*. *Energy Conversion and Management* 52: 1280–1287.

DeVroom D. (2023). What Is Solid Waste? IDR Environmental Services. November 27
<https://blog.idrenvironmental.com/what-is-solid-waste>

Dladla I. Machete F. and Shale K. (2016) A review of factors associated with indiscriminate dumping of waste in eleven African countries. *African Journal of Science, Technology, Innovation and Development* 8: 475–481.

Eneh O.C., and Anamalu N.P. (17). Municipal solid waste management in Enugu: The challenge of public participation. Institute for Development Studies, University of Nigeria, Nsukka.

Eze J. (2021). Urbanization in Nigeria, Enugu (the coal city) as an urban town: A historical review. *Cities*, 113, 103096.

Ezeah C., and Roberts C. L. (2014). Waste governance agenda in Nigerian cities: A comparative analysis. *Habitat International*, 41, 121-128. <https://doi.org/10.1016/j.habitatint.2013.07.007>

Ezeibe C., Nzeadibe C., Ali, A., and Udeogu C. (2017). Work on wheels: Collective organizing of motorcycle taxis in Nigerian cities. *International Development Planning Review*, 39(3), 249–273. <https://doi.org/10.3828/idpr.2017.10>

Ezeh C. C., and Ugwu G. Z. (2010). Geoelectrical sounding for estimating groundwater potential in Nsukka L.G.A. Enugu State, Nigeria. Department of Geology and Mining, Enugu State

University of Science and Technology, Enugu, Nigeria. Department of Industrial Physics, Enugu State University of Science and Technology, Enugu, Nigeria.

Grangxabe X.S., Madonsela B.S., Maphanga T. Gqomfa B., Phungela T.T. and Malakane K.C. (2024). An overview of waste management practices of street vendors in sub-saharanafrica: A meta-analysis. *Journal of Environmental Management* Volume 364, 121464

Hidalgo-Crespo J., Amaya-Rivas J.L., Ribeiro I, Soto M., Riel A. and Zwolinski P. (2023). Informal waste pickers in guayaquil: Recycling rates, environmental benefits, main barriers, and troubles, *Heliyon*, Volume 9, Issue 9. <https://doi.org/10.1016/j.heliyon.2023.e19775>.

Hoornweg, D., and Bhada-Tata, P. (2018). *What a waste: A global review of solid waste management*. Washington: World Bank.

Idris A., Inanc B., and Hassan M. N. (2020.). Overview of waste disposal and landfills/dumps in Asian countries. *Journal*, Volume (Issue), pages. Retrieved from URL (Replace

'Journal Name,' 'Volume,' 'Issue,' 'pages,' and 'URL' with the actual details if available)

Ifeoluwa O.B. (2019) Harmful Effects and Management of Indiscriminate Solid Waste Disposal on Human and its Environment in Nigeria: A Review. *Glob J Res Rev* Vol.6 No.1:1.

Israel B. A., Schulz A. J., Parker E. A., and Becker A. B. (1998). Review of community-based research: Assessing partnership approaches to improve public health. *Annual Review of Public Health*, 19(1), 173-202.

Kaoje I. U., Dankani I. M., and Ishiaku I. (2016). Site Suitability Analysis for Municipal Solid Waste Disposal in Birnin Kebbi, Nigeria. *IOSR Journal of Humanities and social science*, 21(7), 1–10. <https://doi.org/10.9790/0837-2107030110>.

Kimani N. G. (2007). *Environmental pollution and impacts on public health: Implications of the Dandora Municipal Dumping Site in Nairobi, Kenya*. Nairobi: United Nations Environmental Programme.

Komilis D. P., Ham R. K., and Stegmann, R. (1999). The effect of municipal solid waste pretreatment on landfill behavior: A literature review. *Waste Management and Research*, 17, 10-19.

Kookana R.S., Williams M., Boxall A.B.A., Joakim Larsson D.G.³, Gaw S.⁴, Choi K., Yamamoto H., Thatikonda S., Zhu Y. and Carriquiriborde P. (2014). Potential ecological footprints of active pharmaceutical ingredients: An examination of risk factors in low-, middle- and high-income countries. *Philosophical Transactions of the Royal Society B: Biological Sciences* 369(1656): 20130586.

Li, H., Aguirre-Villegas, H. A., Allen, R. D., Bai, X., Benson, C. H., Beckham, G. T., Bradshaw, S. L., Brown, J. L., Brown, R. C., Cecon, V. S., Curley, J. B., Curtzwiler, G. W., Dong, S., Gaddameedi, S., García, J. E., Hermans, I., Kim, M. S., Ma, J., Mark, L. O., Mavrikakis M., Olafasakin O. O., Osswald T. A., Papanikolaou K. G., Radhakrishnan H., Castillo M. A. S., Sánchez-Rivera K.L., Tumu K.N., Van Lehn R.C., Vorst Keith L., Wright M.M., Wu J., Zavala V.M., Zhou P and Huber, G. W. (2022). Expanding plastics recycling technologies: chemical aspects, technology status and challenges. *Green Chemistry*, 24(23), 8899–9002. <https://doi.org/10.1039/d2gc02588d>

Majumder, A. K., and Biswas, W. K. (2022). Municipal solid waste management in developing countries: Future challenges and possible opportunities. *International Journal of Environmental Science and Technology*, 19, 4567-4582.

Magrinho A., Didelet F. and Semiao V. (20017). Municipal solid waste disposal in Portugal. *Waste Management*, 26(12), 1477-1489.

Maheshi D. (2015). Environmental and economic assessment of 'open waste. ScienceDirect. Retrieved from. [HTTP article/abs/pii/S0921344915300379](http://article/abs/pii/S0921344915300379).

Mangizvo V. R. (2010). An overview of the management practices at solid waste disposal sites in African cities and towns. *Journal of Sustainable Development in Africa* (Volume 12, No.7).

McAllister J. (2015). Factors influencing solid waste management in the developing world. [Graduate Plan B or other Reports]. DigitalCommons@USU. Utah State University.

Mebratu D. (2022, November 10). Burning waste must end: African leaders look to recycling for better health and value. *The Conversation*. <https://theconversation.com/burning-waste-must-end-african-leaders-look-to-recycling-for-better-health-and-value->.

Momodu N. S., Dimuna K. O. and Dimuna J. E. (2011). Mitigating the Impact of Solid Wastes in Urban Centres in Nigeria. *Journal of Human Ecology*, 34(2), 125-133. DOI: 10.1080/09 709274.2011.11906377

Mor S., and Ravindra K. (2023). Municipal solid waste landfills in lower- and middle-income countries: Environmental impacts, challenges and sustainable management practices, *Process Safety and Environmental Protection*, Volume 174, Pages 510-530, <https://doi.org/10.1016 /j.psep.2023.04.014>.

Omotayo A.O. (2024). Investigating the drivers of solid waste generation and disposal: evidence from South Africa. *Environ Dev Sustain* (2024). <https://doi.org/10.1007/s10668-024-04987-7>

Nnaji C. C. (2015). Status of municipal solid waste generation and disposal in Nigeria. *Management of Environmental Quality: An International Journal*, 26(1), 53-71. <https://doi.org/10.1108/MEQ-08-2013-0092>

Nnaji C C, Afangideh B C, U., Udokpoh U. and Nnam J. P. (2021). Evaluation of Solid Waste Storage and Disposal Practices in Nsukka, Enugu State. *IOP Conf. Ser.: Mater. Sci. Eng.* 1036 012016

Nnaji, C. C., Ogarekpe, N. M., & Nwankwo, E. J. (2022). Temporal and spatial dynamics of land use and land cover changes in derived savannah hydrological basin of Enugu State, Nigeria. *Environment, Development and Sustainability*, 24, 9598-962

Nsa I. Y., Oyebanji O. O., Igbinigie E. E., and Odunsi A. A. (2021). Floral distribution of a sub bituminous coal dumpsite in Enugu, Nigeria. *Frontiers in Ecology and Evolution*, 9.

<https://doi.org/10.3389/fevo.2021.649954>

Nwosu A.O and Chukwueloka H.E. (2020). A Review of Solid Waste Management Strategies in Nigeria. *Journal of Environment and Earth Science*; Vol.10, No.6.

Nwosu E.O., Orji A. and Yuni D.N. (2017). Environmental hazards and waste management in Nsukka urban metropolis in Enugu State of Nigeria: how much are people willing to pay? *Environmental Hazards* 17(1):1-19. DOI:10.1080/17477891.2017.1340868

Nzeadibe T.C. (2009). Solid waste reforms and informal recycling in Enugu urban area, Nigeria, *Habitat International*, Volume 33, Issue 1, Pages 93-99, <https://doi.org/10.1016/j.habitatint.2008.05.006>.

OECD (2024). Municipal Waste. (indicator). doi: 10.1787/89d5679a-en: <https://data.oecd.org/waste/municipal-waste.htm>

Okereke G.K. O, Okanya A. V, Okereke J. A, Okafor S.C, and Ebiegberi K. (2022). Reducing the Threats of Environmental Factors to Buildings: A Case Study of Nsukka Urban in Enugu, Nigeria. *international Journal of Research and Review*: Vol. 9; Issue: 7. www.ijrrjournal.com

Onyeka T.C. (2011). Palliative care in Enugu, Nigeria: Challenges to a new practice. <https://www.ncbi.nlm.nih.gov/pmc/articles/>

Onuigbo C. I., and Bello E. A. (2014). Assessment and Selection of Suitable Sites for Solid Waste Disposal using Surveying and Geoinformatics Techniques. *International Journal of Engineering Research & Technology (IJERT)*, 3(8), 1685–1692.

Onungwe, I., Hunt, D. V. L., and Jefferson, I. (2023). Transition and Implementation of Circular Economy in Municipal Solid Waste Management System in Nigeria: A Systematic Review of the Literature. *Sustainability*, 15(16), 12602. <https://doi.org/10.3390/su151612602>

Orhorhoro E., and Oghoghorie O. (2019). Review on solid waste generation and management in sub-Saharan Africa: A case study of Nigeria. *Journal of Applied Sciences and Environmental Management*, 23(9), 1729–1737.

Popoola A.A., Ayangbile O.A. and Adeleye B.M. (2016). Assessment of solid waste management systems in Ibadan North, Oyo State using geo-spatial techniques. *Ethiopian Journal of Environmental Studies and Management / Vol. 9 No. 6*

Remigios M.V. (2010). An overview of the management practices at solid waste disposal sites in African cities and towns. *Journal of Sustainable Development in Africa* (Volume 12, No.7).

- Rushbrook P. (1999). Getting from subsistence landfill to sophisticated landfill. *Waste Management and Research*, 17(4), 4-9
- Salamandane A., Malfeito-Ferreira M. and Brito L. (2023). The socioeconomic factors of street food vending in developing countries and its implications for public health: a systematic review *Foods*, 12 (20) (2023), p. 3774
- Ugwu K. C., Echiegu E. A. and Okonkwo W. I. (2017). Waste Generation and Management in Nsukka Urban, Enugu State of Nigeria. *World Journal of Engineering Research and Technology*; Vol. 4, Issue 1, 21-34.
- Ugwuishiwi B.O., Nwodo J.C. and Echiegu E.A. (2016). Municipal solid waste characterization in Nsukka urban in South East Nigeria. *Transylvanian Review*, XXIV (7), 808. *Transylvanian Review*: Vol XXIV, No. 7, Special Issue,
- UNICA (United Nations Economic Commission for Africa) (2009). Africa Review Report on Waste Management. Committee on Food Security and Sustainable Development Regional Implementation Meeting for CSD-18 Sixth Session 27-30 Oct. Addis Ababa, Ethiopia
- Vaverková M. D., Adamcová D., Zloch J., Radziemska M., Boas Berg A., Voberkova S. and Maxianova A. (2018). Impact of municipal solid waste landfill on environment—A case study. *Journal of Ecological Engineering*, 19(4), 55–68.
- Volsuuri E., Owusu-Sekyere E. and Imoro A.Z. (2023). Unequal location, unequal access: the spatial analysis of solid waste disposal services in Northern Ghana. *Discov. Environ* 1, 14. <https://doi.org/10.1007/s44274-023-00011-3>
- Wilson D. C., Rodic L., Cowing M. J., Velis C. A., Whiteman A. D., Scheinberg A., Vilches R., Masterson D., Stretz J. and Oelz B. (2015). 'Wasteaware' benchmark indicators for integrated sustainable waste management in cities. *Waste Management*, 35(11), 329–342.
- Wilson D. C. and Velis C.A. (2015). Waste management—Still a global challenge in the 21st century: An evidence-based call for action. *Waste Manag. Res*, 1049–1051.
- Zurbrugg C. (2003, November). Urban solid waste management in low-income countries of Asia: How to cope with the garbage crisis. Presented at the meeting of Scientific Committee on Problems of the Environment (SCOPE) on Urban Solid Waste Management Review Session, Durban, South Africa.
- Zumo I. M., and Vokna S. A. (2014). Identification of suitable site for solid waste disposal in Yola, Nigeria Using GIS method. FIG Congress: Engaging the Challenges-Enhancing the Relevance (pp. 16-21). Kuala Lumpur, Malaysia.

Plates

Plates 1 to 3 are available in the Supplementary Files section.

Figures

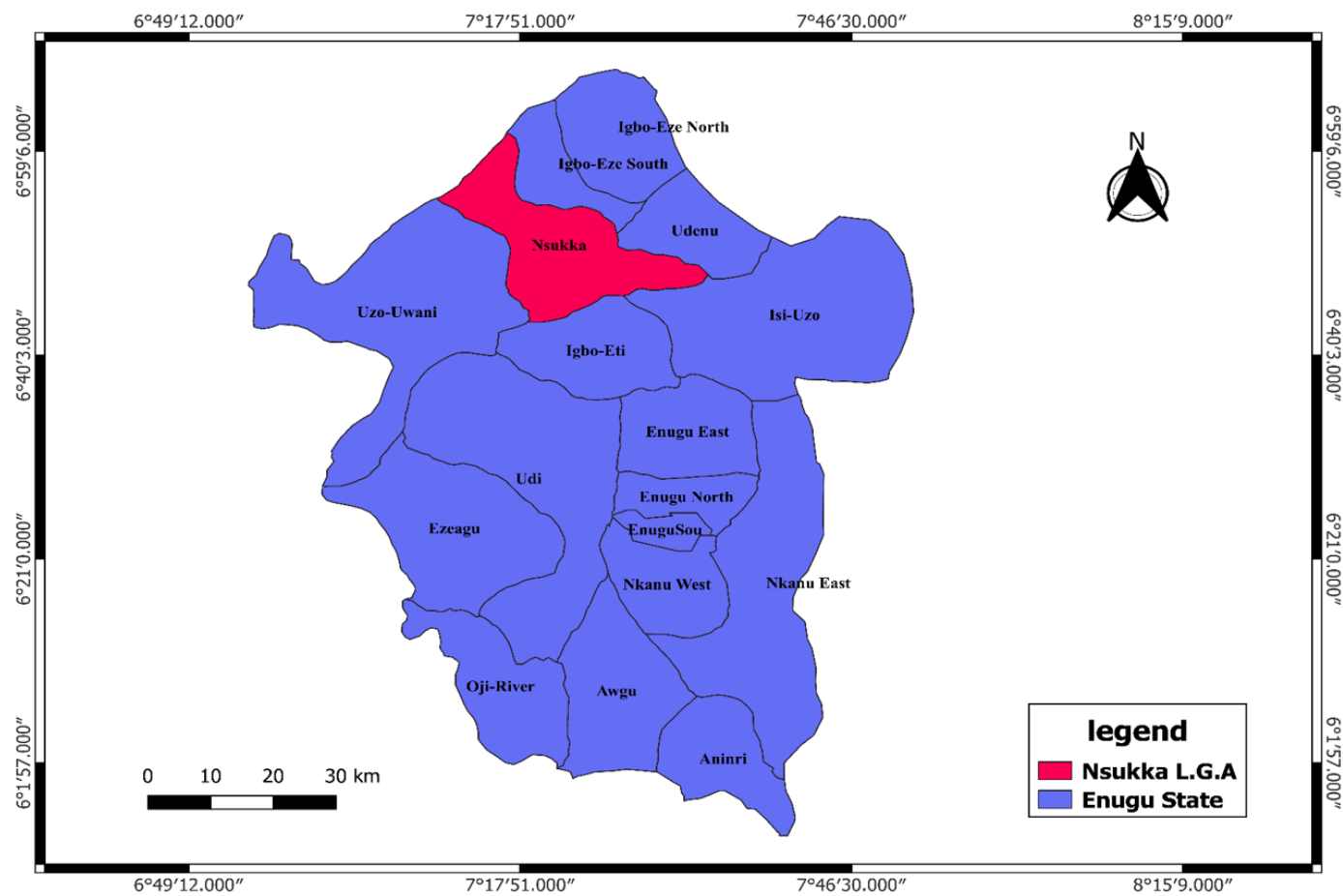


Figure 1
Enugu state showing the Study Area

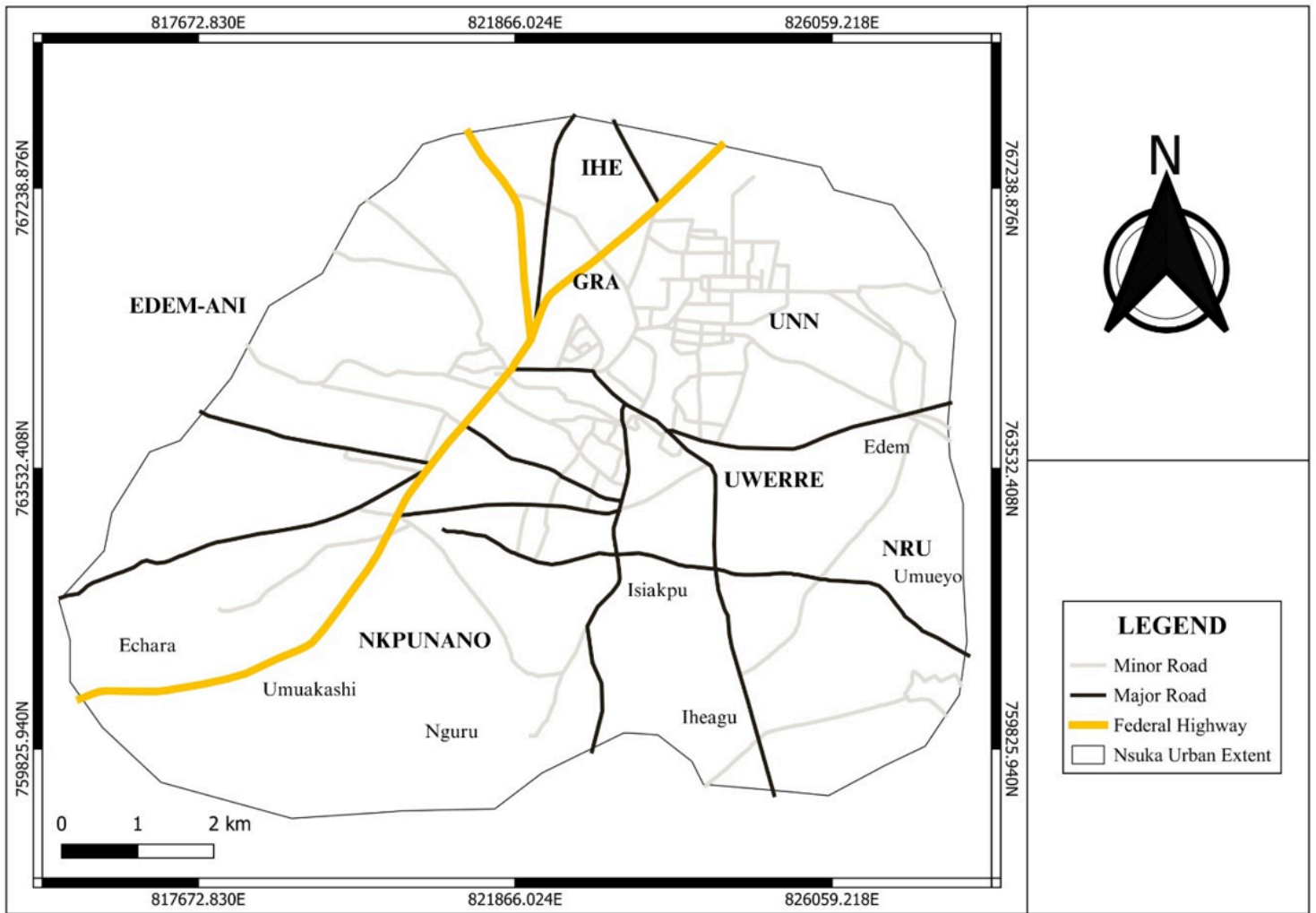


Figure 2

Nsukka Urban

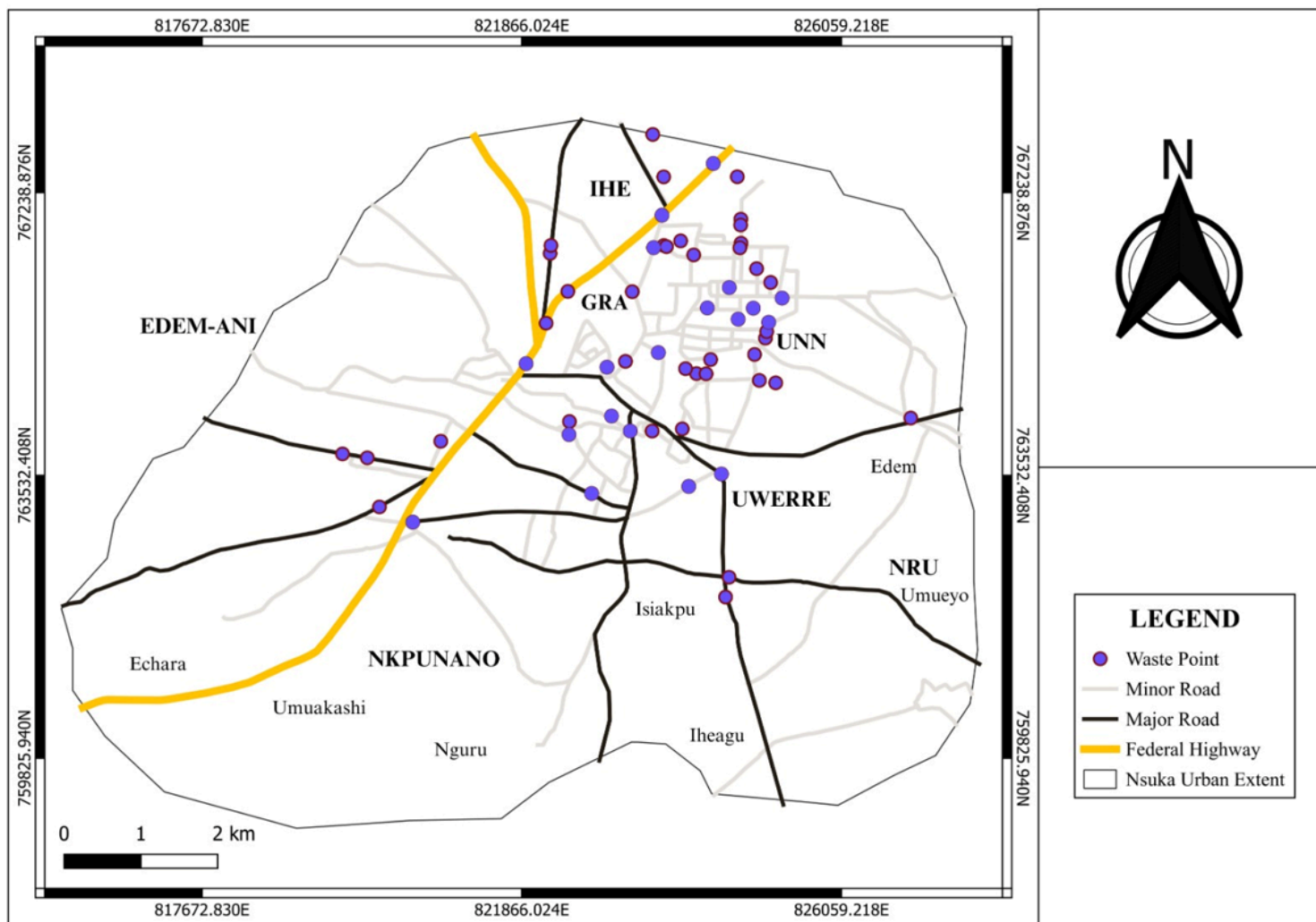


Figure 3

Geospatial distribution of the entire solid waste dump sites in Nsukka Urban

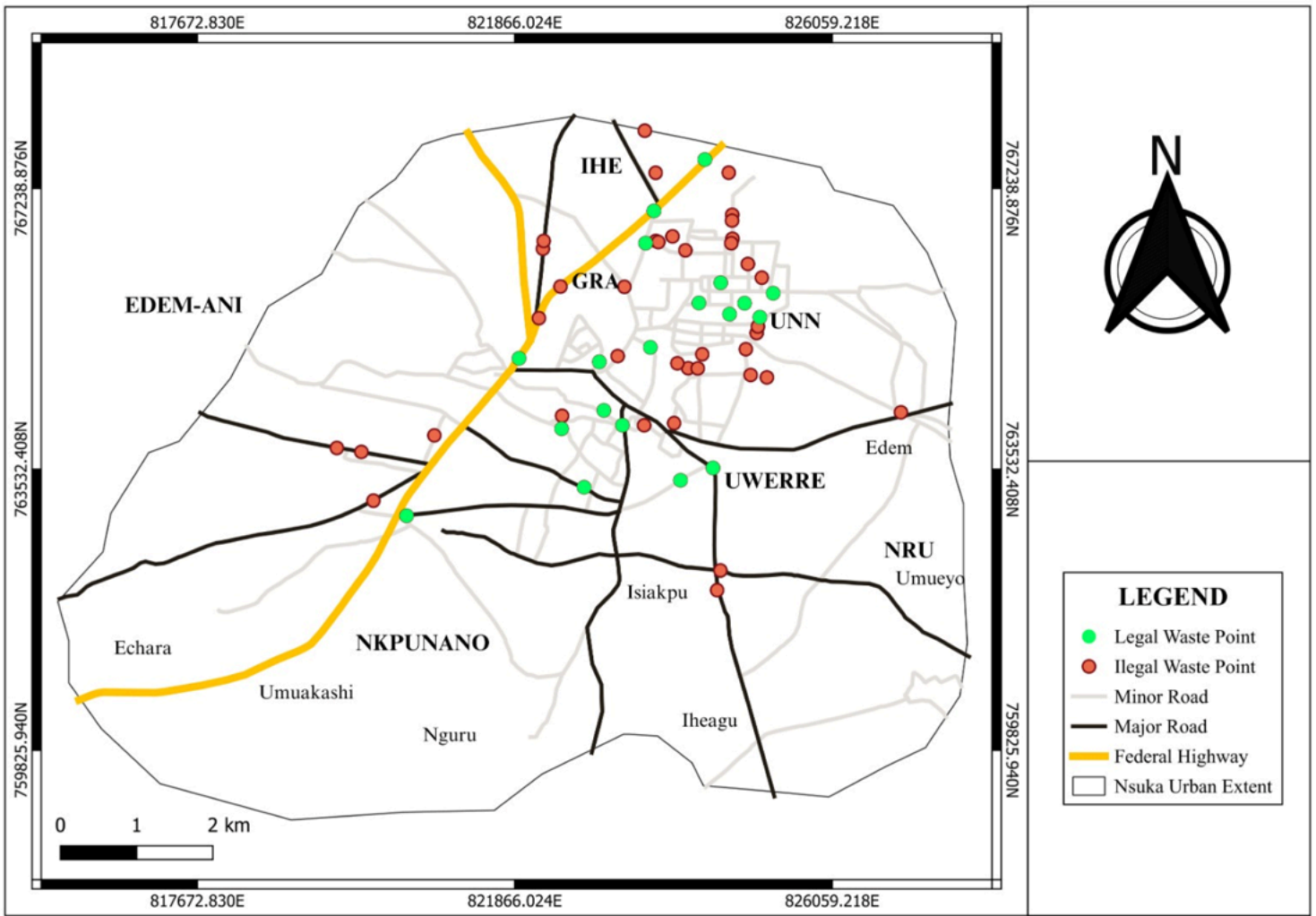


Figure 4

legal and illegal dumpsites within Nsukka Urban.

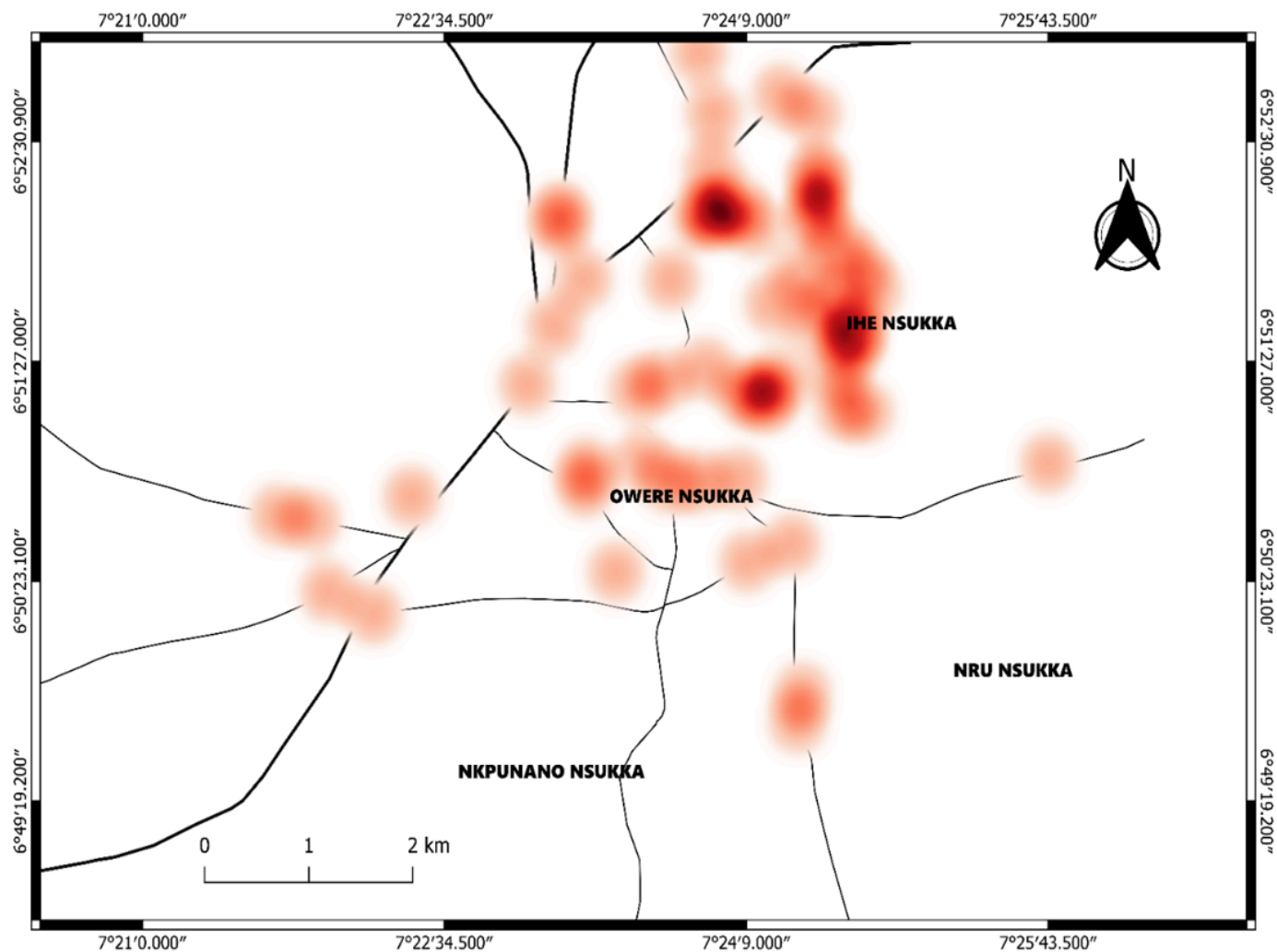


Figure 5

Heatmap Depicting Dumpsites Concentration in Nsukka Urban.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [plate1.png](#)
- [plate2.png](#)
- [plate3.png](#)