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Analysis of the Spatial Distribution of Waste Disposal Points in Calabar: A Humid Tropical City

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Abstract **- The study investigates spatial distribution of waste disposal points in Calabar metropolis, aiming to enhance the city's clean and green status. Multi-stage random sampling technique was used to delineate the metropolis into zones, thereafter stratified sampling technique was adopted to select major and minor streets for data collection. Handheld Global Positioning System was used to collect locational data of waste bins for mapping. From the result of the Average Nearest Neighbour statistical analysis, based on the calculated p-value (0.264053), ANN ratio and z-score, it is evident to accept the null hypothesis which states that the distribution of waste disposal points in Calabar Metropolis is not significantly different from a normal distribution. This therefore affirmed that the selected waste disposal points in Calabar are distributed randomly. The output from the analysis (ANN), further buttressed that the challenges associated with waste collection mostly due to location of waste disposal points revealed that the waste collection bins were randomly distributed but not commensurate to the quantity generated within the study area. Based on the findings of the study, it was recommended among others that the State Government should provide more waste bins in strategic locations and ensure prompt evacuation of waste.**

Keywords: Waste, Spatial distribution, Generation, disposal, Management.

1. Introduction

Urban waste generation and management present a top priority in the environmental agenda of most cities the world over. In time, the challenges assumed an exponential dimension caused by increase in the demographic characteristics of the areas. Going by the fact that urban waste is derived from different sources and materials there is a grave need to direct adequate attention to the clear appreciation of the categories of waste being handled or managed and the best practical approach of speculating and managing them for the avoidance of health burdens that may arise.

Wastes is unwanted or unusable materials (of a primary user which may be useful to a secondary user) seeking to be discarded. Waste disposal points also known as waste collection or recycling centers are locations where individuals and businesses can properly dispose their waste materials. The facilities are designed to handle various types of waste in order to promote proper waste management practices, reduce landfills and protect the environment. Availability of specific waste disposal point in any area depends on local regulations and infrastructure. This may range from recycling centers to household waste collection centers, Hazardous waste collection centers, composting facilities and construction and demolition waste centers.

Substantial evidence exists in the literature concerning the sources, nature, and health implications of waste in general. Following a report from [19], revealed the group at risk from unscientific disposal of solid waste include the population in areas where there is no proper waste disposal method, waste workers and worker in facilities with toxic and infections materials, population living close to a waste dump, those whose water have become contaminated from leakages from landfills etc. Calabar urban waste techniques typify significantly several of the cases mentioned above. From 1999-2007, Calabar was adjudged the cleanest city in Nigeria and fondly referred to as ''clean and green'' but currently the situationhas changed to worst.

Incidents of overstuffed waste receptacles are common features along the streets with reckless abandon. Unsightly spectacles disrupt movement and deteriorate the aesthetic and environmental quality of the metropolis. Most ugly is the central dump site proper, where waste workers, scavengers, youths and other categories of urban poor navigate and rummage the squalid heap without reservation.

Environmental regimes, regional and National environmental agencies, non- Governmental organizations and societal groups have come to recognize the risk associated with poor waste management methods. This recognition has led to a significant transformation in waste management techniques using the most appropriate 'state of the arts'

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scientific practices to ameliorate the health burden it will incur on individuals and the society as a whole. The current approach to waste management by the relevant stakeholders in Calabar metropolis portrays abject neglect and disregard for the impending health and economic peril to the population.

2. Objective and Hypothesis of the Study

The objective is to investigate the spatial distribution of waste disposal points in the study area.

The hypothesis states that the distribution of waste disposal points in Calabar, is not significantly different from a normal distribution.

3. Conceptual Clarification

Waste products are generally considered as rubbish, garbage or something to be discarded. What connote waste is a relative terms. What is wasteful to someone may be useful to another. This corroborates [1] conception that waste is any product or material which is useless to the producer and they are materials that people will want to dispose. Generally they are by products of inefficient production processes. According to [5], waste is externalities caused by conformity of human production process to the second law of thermodynamics which is called the law of decay or entropy. This counteracts the first law of thermodynamic which is properly called "the law of conservation of matter "or "the law of environmental organization".

Substantial amount of waste generation began in the 16th century when people began to move from rural areas to the city as spurred by the onset of the industrial [18]. The revolution facilitated demographic explosion which led to a significant increase in the tonnage and variety of waste produced. It was from this period that materials from metals and glass as well as non-biodegradable or bio accumulative waste started appearing in the waste materials produced [18]. The sheer numerical increase in the people of essence, led to the practice of indiscriminate waste dump or littering in a phenomenon called "litter bugging." The unhealthy waste management practices engendered outbreak of epidemic leading to large death tools [15]. Thus it was in is the 19th century that public attention was paid to waste control and management [13].

The diversity of human activities or occupation in the environment correspondingly determines the sources and variety of waste produced. Most times waste are classified according to their nature and characteristic based on their physical states or properties, reusable potentials, biodegradability, source of production and degree of environmental impact etc. [2], [3]. In line with this, the following categories have been speculated or specified such as

- Physical state: solid waste , liquid waste and gaseous waste
- Source: household/domestic, industrial waste market or commercial waste, demolition and construction waste etc.
- Environmental impact conception: Hazardous (Nocuous) and non-hazardous (innocuous).

An important member of this waste which is of direct relevance to this study is the municipal solid waste. This relates to solid waste from urban centers which are the most explored academically. [16], inferred that municipal solid waste has many implications.

[6], Study on the spatial distribution of waste disposal points in Calabar reveal the deterioration of waste through physical, anthropogenic, and organic processes, resulting in artificially contaminated leach ate which can contaminate groundwater and surface water. [14], utilized the LINGO 11 software, to efficiently handle the maximum amount of household waste generated. Addressing the challenges of solid waste management in urban areas, [7] proposed integrated system that combines Radio Frequency Identification (RFID), Global Positioning System (GPS), General Packet Radio Service (GPRS), Geographic Information System (GIS), and web camera technology to evacuate waste in with superior performance in terms of data transmission speed, precision, real-time monitoring, and reliability compared to existing systems. In the same vein, [8] optimized scenarios using the ArcGIS Network Analyst tool and incorporated data from Geographic Information System (GIS) and GPS tracking to reduce collection time, distance, and fuel consumption in Sfax City, Tunisia, thereby improving the overall efficiency of waste management.

Similarly [10], utilized satellite imagery, GPS data, and topographical maps to map the distribution of solid waste disposal sites in Kano and observed that while the disposal sites were fairly well-distributed, there was a higher concentration in the central part of the metropolis with a significant percentage of the sites located close to roads, settlements, or water bodies.

4. Site Description

Calabar metropolis lies between longitudes 80.18'' to 80.24'' east and latitudes 40.54'' to 500.10'' North of the equator (Fig 1). Calabar is situated on the shores of the Atlantic Ocean on the curve formed by Gulf of Guinea. On this basis it enjoys a marine equable environment as influenced by the incidence of land and sea Breeze. The

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marine coastal environment forms the southern boundary of this territory. Due to its proximity to the equator, it enjoys a subequatorial climate with humid climatic condition [12]. It has double maxima rainfall pattern of approximately 3063mm,[4], with short dry season usually between November and March and relatively longer wet season from April to October. The dry season is dominated by North East trade wind, wind, while the South-East trade wind dominates the wet season. The unique characteristic of high humanity and high rainfall and temperature have culminated into a high complex and diverse flora and fauna. This humid condition contributes significantly in exacerbating the process of putrefaction and decomposition, a common feature of agricultural waste products that predominate the nature of waste produced by residents and other activities carried out by the population. The population of Calabar metropolis in 2006 was 375,196 people however, it is believed that this population from 2006 to 2021 must have increase geometrically, contributing to the quantity of waste generated.

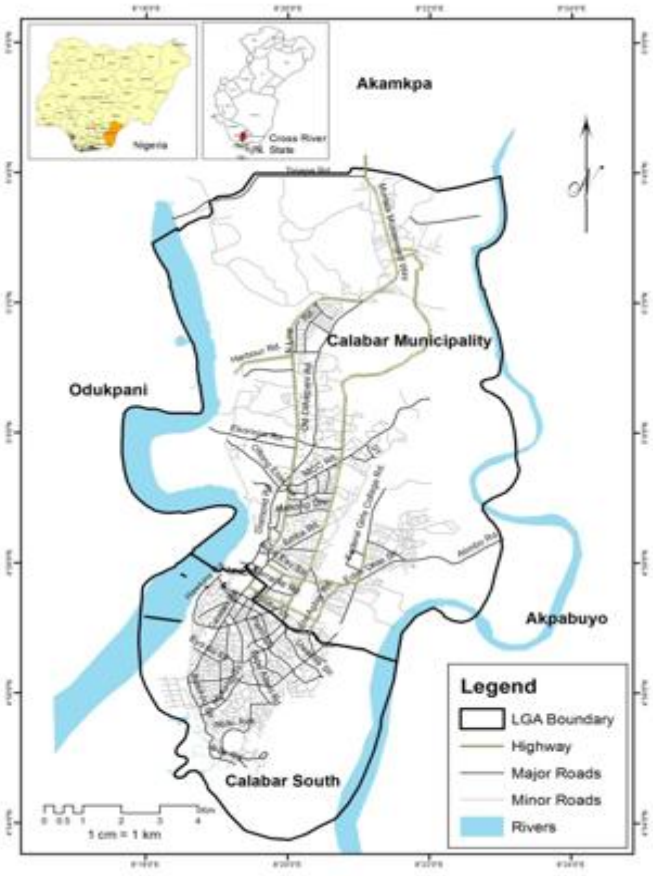

Figure 1: Map of Calabar Metropolis

Source: GIS Unit, Department of Geography and Environmental science, University of Calabar.

5. Materials and methods

The multi-stage random sampling technique proposes by [9] was used to cyclical data on Spatial distribution of waste disposal points. To have a fair coverage of the population in the study area. The metropolis was divided into six (6) zones, three (3) from Calabar Municipality and three (3) from Calabar South. These include Ebito Street, Hart Street, and Atamunu Street, All in Calabar South. Also, Victory way in Satellite Town, Edim-Otop, Diamond Town/ Ekorinim. Spatial framework was used in each zone to facilitate the selection of samples. This division technique aided in bringing out the real differences as regards to solid waste generation and volume of waste generated in each area. The data on spatial distribution of waste disposal points within Calabar metropolis was obtained during field research, using a Garmin Etrex 10 handheld Global Positioning System (GPS). The location data: x (longitude), y (latitude), z (waste disposal points) was derived from the eighty (80) selected locations across the sampled six (6) randomly selected zones in Calabar. The Average Nearest Neighbour (ANN) was used for analysis.

6. Results and discussion

The objective was to investigate the spatial distribution of waste disposal points in the study area.

In testing the hypothesis which states that the distribution of waste disposal points in Calabar, is not significantly different from a normal distribution. The point data (longitude and latitude) of the locations of waste disposal points in Table 1 were used to carry out the analysis.

Table 1: Attribute table of waste bin location points in Calabar Metropolis

SN	Longitude	Latitude	Street Name
1	8.332424	8.332424	White House Street
2	8.333923	8.333923	Ekpo Abasi Street
3	8.336565	8.336565	Yellow Duke Street
4	8.339064	8.339064	Atimbo Road
5	8.338136	8.338136	Essien Town Road
6	8.339242	8.339242	Oron Road
7	8.341133	8.341133	Ndon Edet
8	8.348486	8.348486	Effio-Ette Junction
9	8.358336	8.358336	Etta-Agbor Road
10	8.364190	8.364190	Essien Town Road
11	8.344488	8.344488	Goldie Street
12	8.345916	8.345916	Goldie Street
13	8.351626	8.351626	Asari Eso Layout
14	8.333210	8.333210	Mount Zion Road
15	8.323645	8.323645	Diamond Hill Road
16	8.339064	8.339064	Duke Town Close
17	8.327641	8.327641	Ikot Ansa Street
18	8.333495	8.333495	Abang Asang
19	8.334923	8.334923	Webber Street
20	8.333781	8.333781	Palm Street
21	8.333067	8.333067	Mayne Avenue
22	8.350057	8.350057	Satellite Town Road
23	8.339492	8.339492	Umo Okon
24	8.334352	8.334352	Nsemo Street
25	8.335922	8.335922	James Watt Road
26	8.334923	8.334923	Ayatmo Street
27	8.330069	8.330069	Mary Slessor Avenue
28	8.328284	8.328284	Essien Town Road
29	8.346630	8.346630	New Airport
30	8.338849	8.338849	Etim Effiom

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Table 1: Continued

31	8.322645	8.322645	Goldie Street
32	8.357552	8.357552	Ebito Street
33	8.339563	8.339563	Egerton Street
34	8.340063	8.340063	Anating Street
35	8.360407	8.360407	Etim Edem Road
36	8.355053	8.355053	Barracks Road
37	8.362477	8.362477	Hawkins Road
38	8.368473	8.368473	Ekpo Abasi Street
39	8.352393	8.352393	Ediba Street
40	8.358846	8.358846	Palm Street
41	8.353764	8.353764	Goldie Street
42	8.353364	8.353364	Atamunu Street
43	8.350280	8.350280	Bassey Duke Street
44	8.359646	8.359646	Azikiwe Street
45	8.341143	8.341143	Target Road
46	8.344855	8.344855	Anderson Street
47	8.336288	8.336288	Mount Zion Road
48	8.333719	8.333719	White House Street
49	8.335090	8.335090	Asuquo Ekpo
50	8.331092	8.331092	Palm Street
51	8.328979	8.328979	Goldie Street
52	8.321955	8.321955	IBB Way
53	8.322069	8.322069	Ekpo Abasi Street
54	8.321955	8.321955	Palm Street
55	8.323040	8.323040	Calabar Road
56	8.316701	8.316701	Nyatowo Street
57	8.316987	8.316987	Mount Zion Road
58	8.313788	8.313788	Atamunu Street
59	8.316530	8.316530	Adam Duke
60	8.328351	8.328351	Queen Duke Street
61	8.328979	8.328979	Big Qua Town Road
62	8.312989	8.312989	King Duke Street
63	8.316244	8.316244	Abasi Obori
64	8.319683	8.319683	Marian Road
65	8.321054	8.321054	Eyo Etta Street
66	8.324192	8.324192	Ekpo Abasi Street
67	8.328118	8.328118	Target Road
68	8.334126	8.334126	Old Ikang Road
69	8.328118	8.328118	White House Street
70	8.325060	8.325060	Eta-Agbo Road
71	8.337910	8.337910	Becles Davis
72	8.329201	8.329201	Atakpa Street
73	8.324584	8.324584	Palm Street
74	8.319707	8.319707	Palm Street
75	8.340336	8.340336	Mount Zion Road
76	8.338432	8.338432	Ekpo Abasi Street
77	8.331675	8.331675	Ndidem Usang Iso Road
78	8.331294	8.331294	Murray Street
79	8.336862	8.336862	White House Street
80	8.322109	8.322109	Academy Street
81	8.321140	8.321140	White House Street

The data shows the 81-point locations of selected waste disposal point's spots in Calabar Metropolis (Fig. 2).

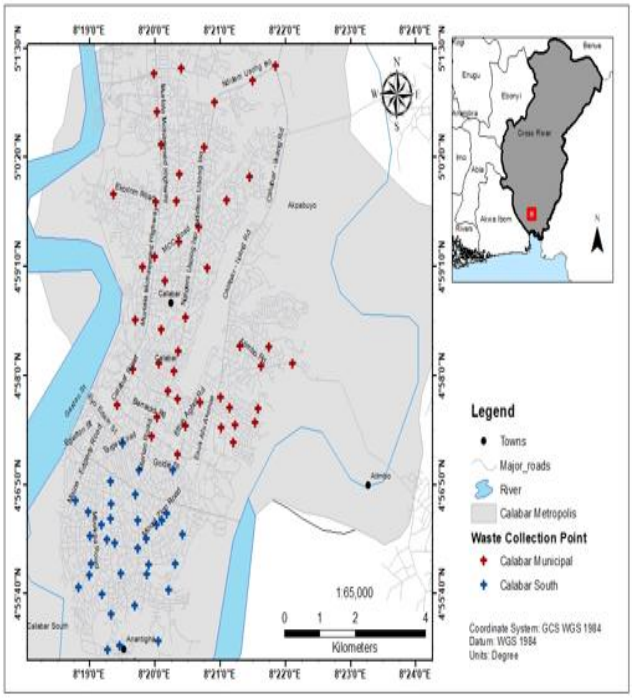
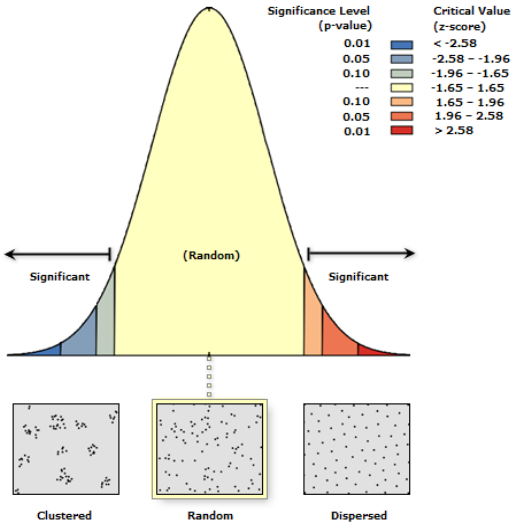


Figure 2: Map showing distribution of waste collection points in Calabar Metropolis

Source: Researcher's fieldwork, 2023.

The Average Nearest Neighbour (ANN) analysis output revealed an index of 0.907, approximately 1, thus, the pattern exhibits randomness. Also, given the z-score of -1.1168, the pattern never appeared significantly different random. This means it is very likely that the seen spatial distribution of waste disposal points is the output of random processes (ESRI, 2013). Based on the calculated p-value (0.264053), ANN ratio and z-score, it is evident to accept the null hypothesis which states that the distribution of waste disposal points in Calabar Metropolis is not significantly different from a normal distribution (Fig. 3).



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Given the z-score of 1.42932390328, the pattern does not appear to be significantly different than random.	
Observed Mean Distance:	498.7993 Meters
Expected Mean Distance:	460.5654 Meters
Nearest Neighbor Ratio:	1.083015
z-score:	1.429324
p-value:	0.152911

Figure 3: Average nearest neighbor analysis output

This therefore affirmed that the selected waste disposal points in Calabar are distributed randomly. The output from the analysis (ANN), further buttressed that the challenges associated with waste collection are mostly due to location of waste disposal points.

Through this spatial analysis, the distribution of waste disposal points across Calabar Metropolis was meticulously delineated and the result returned from the Average Nearest Neighbor revealed that the spatial distribution of waste collection bins exhibits randomness in Calabar Metropolis. This effort shed light on the physical presence and concentration of waste accumulation, forming a crucial foundation for informed waste management strategies. Waste management in Calabar is still very crude compared to other cities who have stepped up their evacuation rate with modern tools and technology in terms ofsuperior performance, transmission speed, precision, real-time monitoring, and reliability,[7]; [8]; [10].

7. Conclusion and Recommendation

The Calabar Metropolis's waste management landscape was meticulously explored through a comprehensive spatial analysis which effectively mapped out the distribution of waste disposal points across the area, offering valuable insights into the concentration and placement of waste bins leading to accumulation. The major challenges range from infrastructural limitations to behavioral hurdles.

The spatial distribution of waste disposal points was observed to be random, emphasizing the need for strategic planning in waste collection infrastructure and a disperse distribution of waste collection bins within the study locale. The research provides valuable data for informed decision-making and policy development. Based on the findings and analysis, the researcher offers the following recommendations to improve waste management in Calabar Metropolis:

a) Increase the number of waste collection bins in areas with inadequate disposal points to ensure proper waste disposal convenience for residents.
b) Enhance waste collection frequency to match the disposal patterns to reduce the chances of overflowing bins and improper waste disposal.
c) Relocate the central dump which engulfed by urban sprawl to the outskirts of the metropolis.

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