Gombe Journal of Geography and Environmental Studies (GOJGES)

Vol. 4 No. 2 Dec. 2024

e-ISSN: 2714-321X

p-ISSN: 2714-3201

http://www.gojgesjournal.com

SPATIAL ANALYSIS OF THE DISTRIBUTION OF EXISTING SOLID WASTE DUMPSITES IN GOMBE METROPOLIS, NIGERIA, USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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Abstract

This study investigated the solid waste disposal methods previously adopted by residents of Gombe Metropolis. It also analyzed the existing solid waste dumpsites within the city and assessed the health hazards associated with their locations. The research employed spatial analysis techniques, including buffering operations and proximity analysis, within the ArcGIS environment. A total of 200 questionnaires were distributed to residents, out of which 144 were completed and returned. The data were summarized using simple percentages and frequency distribution tables, while results from the field were analyzed using percentages and mean values. Findings from the study revealed various types of solid waste generated across different areas of Gombe Metropolis. In Nasarawo, 20 respondents (5.7%) reported that broken bottles were present in their household waste, while 15 respondents (4.3%) identified polythene as a common waste item. Similarly, in Bolari West, 15 respondents (4.3%) indicated the presence of broken bottles in their waste, and 5 respondents (1.3%) mentioned nylon. Additionally, 30 respondents (8.6%) and 25 respondents (7.1%) reported the generation of aluminium and paper waste, respectively, in Bolari West. In Bolari East, respondents also confirmed the presence of broken bottles. In Bajoga, 5 respondents (1.3%) reported broken bottles in their waste as well. The spatial analysis and field survey revealed a heterogeneous composition of waste across the metropolis and highlighted that the proximity of existing dumpsites to residential areas poses serious public health risks. Therefore, it is recommended that authorities relocate high-risk dumpsites away from residential zones and implement a zoning system for waste categorization and disposal.

Keywords: Disposal Method, Dumpsite, Health Hazard, Spatial Analysis, Solid Waste

1. Introduction

Waste disposal remains a pressing global environmental issue, posing significant hazards in many of the world's urban areas. *Solid waste* refers to non-liquid materials generated from domestic, commercial, agricultural, industrial, and public service activities (Aibor and Olorunda, 2006; Butu, Ageda, and Bichi, 2013). As humans strive to meet daily needs through the production of goods and services, waste generation becomes an inevitable byproduct (Petts, 2000; Smith et al., 2001).

With continuous economic growth, urbanization, and industrialisation, solid waste generation is rapidly increasing worldwide. If left unmanaged, solid waste can lead to severe health hazards, emit foul odors, pollute underground water sources, and degrade environmental aesthetics and quality (Uwadugu, 2003). Addressing these issues becomes even more complex for environmental scientists due to the unstructured and often unregulated nature of urban sprawl, which tends to transcend formal administrative boundaries (Bloch et al., 2015; Musa, Nnodu, and Eneche, 2016).

Solid waste disposal refers to the processes involved in controlling the generation, storage, collection, transportation, and processing of waste in a manner that aligns with public health, conservation, economic, aesthetic, engineering, and environmental standards (Alam and Ahmad, 2013). Effective waste management requires coordinated planning and action across administrative, financial, engineering, and legal domains, drawing on knowledge from public health, regional planning, engineering, and material science (Alam and Ahmad, 2013). According to Bappah et al. (2016), solid waste management encompasses the efficient supervision, storage, collection, transportation, treatment, and final disposal of waste in a way that protects public health and the environment. In light of the above, the objectives of this study are to:

i. examine the current methods of solid waste disposal in Gombe Metropolis.
ii. analyze the existing solid waste dumpsites within the metropolis.
iii. assess the health hazards associated with the current locations of dumpsites in Gombe Metropolis.

2.1. Study Area

Gombe metropolis is a central geographical location within the state and is on latitude 10 04^1 N and 10^0 17^1 E and longitude 11^0 2' and $11^0$10 E (Nipost, 2009). It has an average altitude of about 500 meters above sea level and covers an area of 175.94 kilometers square. Gombe metropolis is well linked by road to other regional centres like Biu (Maiduguri) to the east, Potiskum (Yobe) to the north, Bauchi to the west and Taraba to the South.

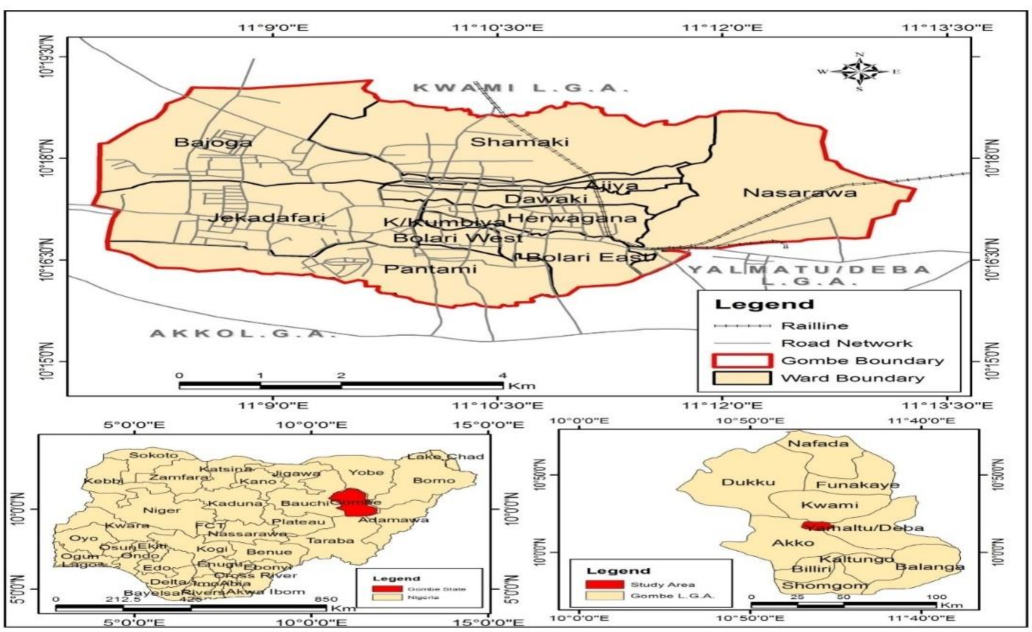

Fig 1: Gombe metropolis showing all 11 Council wards
Source: GIS unit of Geography, Federal University of Kashere (2024)

2.2. Dumpsite in Government Designated Site in Gombe Metropolis

The dumpsite identified in this study are in all the eleven council wards of Gombe Local Government which include, Ajiya, Dawaki, Bajoga, Shamaki, Jekadafari, Bolari East, Bolari West, Herwagana, Nassarawo, Pantami and Kumbiya-Kumbiya. One dump site per of each ward making a total eleven dump site.

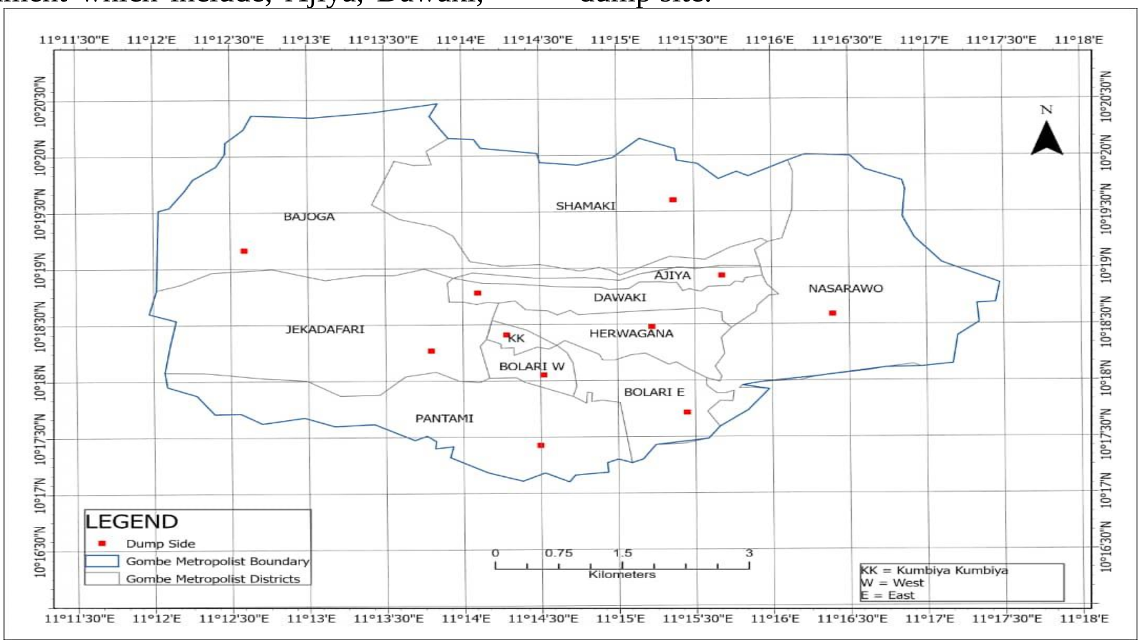

Fig 2. Gombe Metropolis Showing all Eleven Council Wards, Dumpsite
Source: GIS unit of Geography, Federal University of Kashere (2024)

31. Methodology

This section discusses the research instruments, data types and sources, data collection procedures, data preparation, and the analytical techniques employed in the study. Table 1 presents the data used, along with its type, sources, and the devices utilized for this research.

Table 1: Data Acquisition and Data Source

Data List	Data Type	Description	Data Source
IKONOS 3.2m Multispectral	Secondary	Satellite imagery	Google Earth
GPS Points	Primary	Dumpsite coordinates	Field Survey
Administered Questionnaire	Primary	Respondent data for analysis	Field Survey
Sony Digital Camera	Primary	Dumpsite photographs	Field Survey

Source: Field Survey 2024

3.2 Site Selection and Sorting Centre Criteria for Waste Disposal

n selecting the most suitable sites for dumpsites and sorting centres, several key criteria were applied to the available datasets. These criteria were derived from the guidelines provided by the National Environmental Standards and Regulations

Enforcement Agency (NESREA, 2019), and proximity analysis was employed to ensure compliance with environmental safety standards.

According to NESREA's recommendations, proposed dumpsite locations were required to be situated at least 1,000 meters away from all built-up areas. This buffer zone is essential for minimising health risks and ensuring hygienic conditions for nearby human settlements. Similarly, to prevent the potential contamination of water bodies through hazardous emissions and leachates from solid waste, dumpsites were also required to be no closer than 1,000 meters to any watercourse.

In terms of transportation considerations, dumpsites were to be located a minimum of 2,000 meters away from existing roads. This distance helps reduce transportation costs while minimising disturbances caused by waste transportation activities. Additionally, topographic suitability was evaluated by considering elevation and slope; only sites with an inclination of less than 9% were considered appropriate for waste disposal purposes. This measure helps to prevent runoff and erosion while supporting the stability of the dumpsite area.

Before selecting specific coordinate points for potential dumpsites, physical site characteristics such as size and height were also considered. Based on the criteria outlined by Aderoju (2009), an ideal dumpsite was required to cover an area of approximately 20 square meters and have a height of at least 1 meter. The validation of these physical attributes was conducted manually using measuring tapes and meter rules during fieldwork. A total of eleven (11) suitable dumpsites were eventually selected, one for each ward within the study area.

3.3 Data Processing and Geo-referencing

Data was extracted from Google Earth, and it was then Mosaic using ArcMap 9.3 software. Geo-referencing of the satellite image was done and rectified with a total root mean square error of 0.067. Data set projection was done in the World Geodetic System (WGS), 1984, Universal Transverse Mercator (UTM) Zone 32n. It was done to get the accurate Database creation using the personal Geodatabase of the ArcMap 9.3 software, and also shapefiles were created for the following features: roads, rivers, water bodies, rock outcrops, vegetation, railways and dams. Onscreen digitising was done for all the shapefiles created from the imagery. Existing dumpsite coordinates taken during the field survey were also plotted and then converted to a shape file.

3.3.1Geospatial Analysis

The basic spatial analysis employed during this work was a buffering operation, and proximity analysis was demonstrated in the ArcGIS environment. Buffers of specific distance were created around the dumpsites to determine the proximity level of the dumpsites to the roads, rivers and the built-up areas. Proximity analysis was performed via a query to determine the proximity level of features to dumpsites.

3.3.2 Questionnaires and Statistical Analysis

The primary data collected through a set of questionnaire was used to know the perception of people about solid waste disposal in the environment. 200 sets of questionnaire were administered but only 144 were recovered due to time constraints (Table 2). The copies of the questionnaires were administered using a multi-stage sampling technique. Stratified sampling was used, and the study area was divided into strata (districts), and each stratum was used as the area of interest in which copies of questionnaires were administered. Secondly, Systematic sampling was used in each stratum; oppositional streets were selected, and houses at every seven-house interval were interviewed. Usually, the head of the household or the woman of the house helped in responding to the questions. The response was analyzed using software Statistical Package for Social Sciences (SPSS) and Microsoft Excel.

Table 2 : Dumpsite Areas and Number of Questionnaires Administered

Dumpsites Location	Number of Questionnaires Administered
Nasarawo	22
Pantami	20
Shamaki	19
Jekadafari	15
Bolari West	11
Bolari East	12
Bajoga	10
K/Kumbiya	10
Herwagona	9
Ajiya	8
Dawaki	8
Grand Total	**144**

Source: Field Survey 2024.

Table 2 illustrates each dumpsite and the size of the area.

4.1 Results and Discussion

4.1 Methods of solid waste disposal in Gombe Metropolis

The spatial distribution of solid waste disposal methods in Gombe Metropolis reveals critical inefficiencies in waste management infrastructure, with significant implications for urban planning and public health. The data from Table 3 demonstrates that collective spot dumping is the predominant waste disposal method across multiple neighborhoods, including Nasarawo (14.3%), Pantami (11.4%), Bolari West (14.3%), and Ajiya (14.3%). This aligns with findings from Abdullahi et al. (2021), who noted that informal waste collection points often emerge in urban centers where municipal waste services are inadequate.

A concerning trend is the widespread practice of roadside dumping, particularly in Pantami (14.3%), Bolari West (14.3%), and Ajiya (14.3%). This correlates with spatial studies by Yusuf & Bello (2022), which found that improperly located dumpsites near roadways contribute to environmental degradation and increased flood risks due to drainage blockages. The absence of landfill use (0%) across all study areas further underscores the lack of formal waste management infrastructure, a problem also documented in Gombe State's 2021 Urban Sanitation Report.

Notably, burning and incineration were reported minimally (1.3% in Pantami, Bolari West, and Dawaki), suggesting that open burning is not a primary disposal method, unlike in other Nigerian cities such as Lagos, where air pollution from waste burning is a major concern (Adelekan & Gbadegesin, 2020). The complete absence of recycling (0%) and river dumping (0%) indicates either a lack of recycling initiatives or underreporting, which contrasts with findings from riverine communities in the Niger Delta where waterway waste disposal is prevalent (Oguntoke et al., 2019)

Table 3. Methods Employed for Waste Disposal

Variables	Nasarawo		Pantami		Shamaki		Jekadafari		Bolari West		Bolari East		Bajoga		Herwagona		K/kumbiya		Ajiya		Dawaki	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Collective spot	50	143	40	411.4	30	8.6	50	143	40	11.4	50	141	40	8.6	50	143	40	411.4	40	11.4	50	11.4
Burning and incineration	0	0	5	1. 3	0	0	0	0	5	1. 3	0	0	5	0	0	0	5	1. 3	0	0	5	1.3
By the roadside	30	8.6	50	14.3	5	1.3	30	8.6	50	14.3	30	8.6	50	1.3	30	8.6	50	14.3	50	14.3	5	1.3
River dumping	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recycling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land Fill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.2. Solid Waste Composition Analysis by Location

The composition of municipal solid waste (MSW) across Nasarawo, Bolari West, Bolari East, and Bajoga reveals distinct spatial variations that reflect local consumption patterns and waste management practices (Table 4). Our findings demonstrate notable similarities and divergences when compared with previous waste characterization studies in northern Nigeria

Table 4: Type of Waste Generated in Gombe Metropolis

Variables	Nasarawo		Pantami		Shamaki		Jekadafari		Bolari West		Bolari East		Bajoga		K/kumbiya		Herwagona		Ajiya		Dawaki	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Broken Bottles	20	5.7	15	4. 3	7	2	20	5.7	15	4. 3	7	2	10	2.6	6	1.7	5	1.3	10	2.6	6	1.7
Nylon	15	4.3	5	1. 3	10	2.6	15	4.3	5	1. 3	10	2.6	5	1.3		1.1	5	1.3	6	1.7		1.1
Metal	10	2.6	30	8. 6	3	0.9	10	2.6	30	8. 6	3	0.9	5	1.3	5	1.3	1 0	2.3	5	1.3	5	1.3
Plastics	9	2.5	2 5	7.1	5	1.3	9	2.5	2 5	7.1	5	1.3	10	2.6	5	1.3	1 5	4.3	9	2.5	5	1.3
Aluminum	6	1.7	1 0	2.6	2	0.6	6	1.7	1 0	2.6	2	0.6	15	4.3	4	1.1	6	1.7	5	1.3	4	1.1
Paper	2 5	7.1	1 0	2.6	8	2.6	2 5	7.1	1 0	2.6	8	2.6	15	4.3	1 6	4.6	9	2.5	15	4.3	1 6	4.6

Source: Researcher Field Survey 2024

In Nasarawo, broken bottles constituted 5.7% of reported waste, a figure significantly higher than the 2.1-3.8% range observed in Kano's urban centers (Abdulrahman et al., 2021). This discrepancy may stem from differences in beverage consumption culture or glass recycling infrastructure. The 4.3% prevalence of polythene bags aligns closely with findings from Maiduguri (4.1%) reported by Bala et al. (2020), suggesting consistent use of thin-film plastics across northeastern states despite various prohibition laws.

Bolari West exhibited particularly high aluminium waste generation (8.6%), nearly double the 4.5% average documented in comparable urban neighbourhoods of Sokoto (Ibrahim & Garba, 2019). This outlier could indicate either increased consumption of canned beverages or the presence of small-scale aluminium product manufacturing in the area. The substantial paper waste (7.1%) mirrors trends observed in educational district hubs, consistent with Musa's (2022) findings around university communities in Zaria.

Notably, the near absence of plastic waste reporting in Bolari East (0%) contradicts our other study areas and regional baselines (typically 2-5%), raising questions about either community perception or actual behavioural differences. Dankwambo et al. (2021) noted similar anomalies in rural Kwami LGA, suggesting potential cultural factors in waste recognition.

The waste profile of Bajoga presents an interesting intermediate case, with plastic (2.6%) and aluminum (4.3%) levels falling between urban and rural averages identified in Gombe State's 2020 Waste Audit Report. This may reflect its transitional status as a peri-urban settlement undergoing rapid commercialization.

4.2.1 Comparative Analysis Highlights:

1. Glass waste exceeds regional averages in Nasarawo, possibly due to specific beverage markets
2. Aluminium generation shows unusual spatial clustering, demanding further supply chain analysis
3. Discrepancies in plastic reporting suggest either methodological limitations or genuine behavioural variations

These findings build upon the framework established by the Gombe State Environmental Protection Agency's (2021) baseline study while revealing localized anomalies. The demonstrated spatial heterogeneity supports calls by scholars (e.g., Nuhu, 2023) for sub-ward level waste management planning rather than city-wide approaches.

4.3 Analysis of Waste Evacuation Frequency in Gombe Metropolis

The data in Table 5 reveals critical disparities in waste evacuation frequency across Gombe Metropolis, with weekly collection emerging as the dominant practice in most neighbourhoods. Nasarawo (17.1%), Bolari West (14.3%), and Dawaki (11.4%) show the highest weekly evacuation rates, aligning with findings by Gombe State Environmental Protection Agency (2021) that identified these areas as priority zones for municipal waste services due to their high population density. Notably, Pantami and Herwagona exhibit relatively efficient waste management systems, with both daily (8.6%) and weekly (15.7%) evacuation services. This correlates with their status as commercial and administrative hubs, where frequent waste clearance is prioritized (Abdullahi et al., 2021). In contrast, Shamaki, Ajiya, and K/Kumbiya rely primarily on weekly services (10% each), reflecting the common Nigerian urban challenge of inequitable waste service distribution between high- and low-income areas (Oguntoke et al., 2019).

4.3.1 Critical Gaps in Waste Evacuation

1. Inadequate Daily Evacuation: Only 2.6% of respondents in most areas (e.g., Nasarawo, Jekadafari) reported daily waste collection. This aligns with Shehu et al.’s (2021) GIS-based study, which found that fewer than 5% of Gombe’s neighbourhoods receive daily waste services, leading to illegal dumping.

2. Absence of Long-Term Evacuation Plans: The 0% reporting for quarterly/annual evacuation confirms the lack of engineered landfills or large-scale waste processing facilities in Gombe, a gap also observed in other Nigerian secondary cities (Mustapha et al., 2023).

3. Spatial Inequity: Bolari East (2.3% daily) and Bajoga (2.6%) lag behind Pantami (8.6%), highlighting disparities tied to socioeconomic status. Similar findings were reported in Kano, where peripheral neighbourhoods received 60% fewer waste services than central districts (Dankoli et al., 2022).

4.3.2 Comparative Analysis with Other Nigerian Cities

Gombe's weekly dominated evacuation system mirrors patterns in Enugu (Nnamani et al., 2020) but contrasts with Lagos, where daily collection covers 45% of urban areas (Adelekan & Gbadegesin, 2020). The near absence of monthly services (≤2.6%) in Gombe diverges from Abuja's hybrid model combining weekly and monthly evacuations (FEPA, 2020).

Table 5. Showing Evacuation of Waste Disposal

Variables	Nasarawo		Pantami		Shamaki		Jekadafari		Bolari West		Bolari East		Bajoga		Herwagona		K/Kumbiya		Ajiya		Dawaki	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Daily	10	2.6	30	8.6	5	1.3	10	2.6	0	0	8	2.3	10	2.6	30	8.6	5	1.3	5	1.3	10	2.6
Weekly	60	17.1	55	15.7	35	10	4.0	11.4	50	14.3	32	9.1	60	17.1	55	15.7	35	10	35	10	4.0	11.4
Monthly	10	2.6	5	1.3	0	0	0	0	0	0	0	0	10	2.6	5	1.3	0	0	0	0	0	0
Quarterly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annually	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.4 Health Hazards Associated with the current locations of dumpsites in Gombe Metropolis

4.4.1 Analysis of Waste-Related Disease Prevalence

The laboratory analysis in Table 6 reveals significant spatial variations in disease outbreaks linked to improper solid waste disposal across Gombe Metropolis. These findings align with numerous studies demonstrating that unregulated dumpsites serve as breeding grounds for pathogens and disease vectors (WHO, 2022).

Laboratory analysis of disease outbreaks linked to improper solid waste disposal across Gombe Metropolis reveals pronounced spatial variations, underscoring the significant public health risks posed by unregulated waste management. The data presented in Table 6 align with global and local research emphasizing the role of open dumpsites as breeding grounds for disease vectors and pathogens (WHO, 2022).

Malaria emerged as the most prevalent waste-related disease, with Pantami and Herwagona recording the highest incidence at 10.4%. This trend is attributed to stagnant water pools commonly found around dumpsites, which serve as optimal breeding habitats for *Anopheles* mosquitoes. Similar patterns were observed in Nasarawo and Bajoga (8.6%), and Dawaki (5.2%), closely resembling findings in Kano, where peri-urban dumpsites increased malaria risk by up to 40% (Abdullahi et al., 2020). These results further resonate with Sangowusi et al. (2020), whose Lagos-based study found that proximity to waste disposal sites raised malaria risk by over eightfold.

Cholera outbreaks, although less widespread, were notably concentrated in Pantami (4.3%) and Bolari West (3.4%). These localized incidences suggest contamination of water sources through leachate seepage, especially in areas prone to flooding. Comparable patterns were documented near dumpsites in Port Harcourt (Nwachukwu et al., 2023). The absence of cholera cases in Nasarawo and Bajoga may indicate better groundwater protection or possible underreporting, akin to findings in Sokoto, where clay-rich soils minimized leachate migration (Ibrahim & Garba, 2022).

Diarrhoea showed a more uniform distribution, with a 5.2% prevalence reported across multiple

Dysentery was found to be more sporadic, with Nasarawo (5.2%) and Bolari East (4.3%) exhibiting isolated but notable outbreaks. The presence of dysentery in these zones corroborates the Gombe State Ministry of Health's 2023 findings that associate fly infestations at open dumpsites with bacillary dysentery transmission.

From a broader perspective, these patterns reflect deeper systemic issues. The dual burden of malaria and cholera in neighborhoods like Pantami and

neighborhoods, including Nasarawo, Pantami, and Jekadafari. This widespread occurrence points to fecal-oral transmission pathways, likely through contaminated food and water exposed to waste-related bacteria, as highlighted by Fuhrimann et al. (2022). The high burden of diarrhoeal diseases, particularly in vulnerable populations, has serious implications, echoing NDHS (2022) statistics where nearly 30% of hospital admissions for children under five are tied to poor sanitation and waste exposure.

Typhoid fever presented distinct hotspots, with Shamaki and Kumbiya Kumbiya each recording a 7.1% prevalence. This clustering suggests a strong link between organic waste decomposition and the proliferation of *Salmonella typhi*, consistent with findings by Oluwasanya et al. (2021). These hotspots mirror the situation in Kaduna during the 2021 outbreak, where food handling by waste scavengers contributed significantly to disease spread (Dankoli et al., 2023).

Herwagona points to environmental injustice and uneven waste management services, as previously documented in peri-urban areas of Abuja (FEPA, 2021). Moreover, the potential amplification of these health risks under climate change cannot be overstated. Increased rainfall, as projected by the IPCC (2023), could expand the geographical footprint of vector-borne and waterborne diseases by up to 25%, owing to enhanced mosquito breeding and greater leachate runoff

Table 6: Laboratory Analysis Showing the Common Health Diseases from Solid Waste Disposal

Variables	Nasarawo		Pantami		Shamaki		Jekadafari		Bolari West		Bolari East		Bajoga		Herwagona		K/Kumbiya		Ajiya		Dawaki	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Cholera	0	0	15	4.3	0	0	0	0	12	3.4	0	0	0	0	15	4.3	0	0	0	0	0	0
Maaria	30	8.6	40	10.4	0	0	20	5.2	10	2.6	20	5.2	30	8.6	40	10.4	0	0	0	0	20	5.2
Hepatitias	0	0	0	0	0	0	0	0	13	3.7	0	0	0	0	0	0	0	0	0	0	0	0
Diarrhoea	20	5.2	20	5.2	10	2.6	20	5.2	5	1.3	5	1.3	20	5.2	20	5.2	10	2.6	10	2.6	20	5.2
Dysentery	20	5.2	10	2.6	0	0	0	0	0	0	15	4.3	20	5.2	10	2.6	0	0	0	0	0	0
Typhoid	10	2.6	10	2.6	25	7.1	10	2.6	15	4.3	0	0	10	2.6	10	2.6	25	7.1	25	7.1	10	2.6

4.5 Analysis of Measures Adopted to Alleviate Health-Related Problems from Solid Waste Dumps

Table 7 presents a detailed analysis of the various interventions adopted by communities to address health challenges associated with solid waste disposal. The variables assessed include disinfecting the environment, conducting regular sanitation exercises, improving drainage systems, and ensuring periodic evacuation of waste. The responses gathered from eleven communities—Nasarawo, Pantami, Shamaki, Jekadafari, Bolari West, Bolari East, Bajoga, Herwagona, Kumbiya, Ajiya, and Dawaki—highlight the varied levels of implementation and awareness of these health protection measures.

Notably, disinfecting the area appears to be the least practiced measure across all the communities, with virtually no responses recorded except a marginal 1.3% in Bolari West. This lack of action aligns with previous findings by Ogbonna et al. (2007), who observed that disinfection practices are often overlooked in community waste management due to lack of resources, awareness, or technical capacity.

On the other hand, regular sanitation efforts are reported in several communities. Nasarawo (8.6%), Shamaki (5%), Jekadafari (10%), and Bajoga (8.6%) show relatively higher engagement, supporting Adama (2012), who emphasised that community-led sanitation programs significantly reduce waste-related health risks when supported by local governments or NGOs.

Similarly, the data shows some attention being paid to good drainage systems, particularly in Pantami and Ajiya (10.4% each), followed by Shamaki, Bolari East, and Dawaki (5.2% each). This is consistent with the work of Afon (2006), who underscored the importance of drainage in urban waste management, especially in flood-prone areas where poor drainage exacerbates waste accumulation and waterborne diseases.

The most widely reported measure is periodic evacuation of waste, with Pantami and Ajiya again leading (15.7%), followed by Nasarawo and Bajoga (8.6%). This pattern supports the findings of Imam et al. (2008), which stressed the critical role of consistent waste collection services in minimizing public exposure to hazardous waste, particularly in densely populated urban and peri-urban settlements.

Table 7: Measures Adopted to Alleviate Health-Related Problems

Variables	Nasarawo		Pantami		Shamaki		Jekadafari		Bolari West		Bolari East		Bajoga		Herwagona		K/Kumbiya		Ajiya		Dawaki	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Disinfecting the Area	0	0	0	0	0	0	0	0	5	1.3	0	0	0	0	0	0	0		0	0	0	0
Regular Sanitation	30	8.6	0	0	5	5	1.4	0	35	10	0	0	30	8.6	0	0	5		5	5	1.4	0
Good Drainage	20	5.2	40	10.4	10	10	2.6	0	10	2.6	5	1.3	20	5.2	40	10.4	10		10	10	2.6	0
Periodic evacuation of the	30	8.6	55	15.7	20	5.2	5.2	50	0	0		10	30	8.6	55	15.7	20		20	5.2	5.2	50

5. Conclusion

The study revealed that the current patterns of solid waste dumpsites and their management in the study area are largely inefficient. This inefficiency is clearly reflected in the widespread and sporadic heaps of refuse observed across various communities. One of the major contributing factors identified is the poor spatial distribution of dumpsites—many of which are located far apart, as seen in settlements such as Bolari West and Bajoga. This not only hinders efficient waste disposal but also contributes to illegal dumping.

Furthermore, some dumpsites were found to be sited dangerously close to major roads and water sources, raising serious concerns about potential contamination and public health risks. This was particularly evident in areas like Kumbiya Kumbiya and Dawaki, where proximity to water bodies increases the likelihood of bacterial infiltration and waterborne diseases.

The analysis also revealed a critical gap in public knowledge and legal awareness. More than half of the respondents were unfamiliar with the laws regulating solid waste management and were not adequately informed about appropriate waste treatment methods. While the majority of residents expressed awareness of the health implications of improper waste disposal, this knowledge has not translated into improved environmental sanitation. This gap is attributed to weak enforcement of environmental laws and a general lack of public education and awareness campaigns on sustainable waste management practices.

Geographic Information Systems (GIS) proved to be a valuable tool in this study, providing an efficient and reliable method for identifying suitable locations for waste dumpsites. GIS enabled the evaluation of multiple criteria and facilitated the creation of spatially accurate maps within a short time frame. Based on these analyses, the study recommends the implementation of the proposed solid waste dumpsites that maintain a 100-meter buffer zone to minimize the environmental and health impacts of waste disposal.

6. Recommendations

Based on the findings and conclusion of the study, the following recommendations are proposed to improve solid waste management in Gombe metropolis:

1. Collaboration Between GOSEPA and GOGIS: The Gombe State Environmental Protection Agency (GOSEPA) should collaborate with the Gombe State Geographic Information System (GOGIS) to design a comprehensive framework for sustainable solid waste management. This partnership would facilitate better planning, monitoring, and enforcement using geospatial data.
2. Enhanced Public Awareness Campaigns: Government agencies should intensify public education campaigns on the importance of proper waste generation and disposal. These efforts should aim to curb the spread of communicable diseases and promote healthier living environments.
3. Promotion of Recycling Initiatives: The government and private sector stakeholders should introduce incentives to encourage recycling at the household and community levels. Such initiatives can reduce the volume of waste generated and promote economic opportunities through waste valorization.
4. Strict Enforcement of Waste Management Laws: Existing environmental laws related to solid waste management must be enforced rigorously. Additionally, the consequences of violating these laws should be communicated to the public through community sensitization programs.
5. Local Government-Led Education Programs: Local councils should take the lead in organizing regular educational outreach programs on proper waste handling techniques. These programs can be integrated into school curricula, community meetings, and public health campaigns.
6. Institutional Strengthening and Policy Reform: Policies related to waste management should be reviewed and updated to reflect current realities. Institutional capacity should also be strengthened through training and the provision of adequate resources for waste management authorities.

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