

Geospatial Assessment of Water, Sanitation and Environmental Health Factors Associated with Cholera Outbreaks in Selected Unregulated Premises in Minna Metropolis, Niger State, Nigeria

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ABSTRACT

Cholera epidemics continue to recur in Minna metropolis, Niger State, and are often met with episodic emergency responses, indicating persistent environmental and sanitation-related risk factors. This study investigated water, sanitation and environmental health factors associated with cholera occurrence in selected unregulated premises in Minna metropolis. A descriptive cross-sectional study with a geospatial component was carried out. Data from 254 operators were collected using questionnaires and observational checklists, with 254 premises mapped using GIS. Cholera data for 2020–2025 were obtained from the Niger State Ministry of Health to further support these instruments. The findings of the study revealed that poor WASH conditions were widespread in the study area. Water source ($\chi^2 = 68.42$, $p < 0.001$), waste disposal ($\chi^2 = 82.15$, $p < 0.001$), and sanitary condition ($\chi^2 = 45.67$, $p < 0.001$) were significantly associated with cholera occurrence. No significant differences were found between the two LGAs with Minna metropolis ($p > 0.05$). Even though 79.9% reported high hygiene awareness, appropriate practices were inconsistent. A significant hot spot was identified around Minna South and the David Mark Road/Maitunbi corridor ($G_i^ z \approx +0.87$, $p = 0.048$), while the Bosso/Tutugo/Korpkpa Tutugo corridor showed a significant cold spot ($G_i^* z = -1.155$, $p = 0.001$). The study concludes that unsafe water, poor waste disposal and inadequate sanitation may increase cholera risk. Improved WASH interventions, regular inspections and stronger enforcement are recommended, particularly in identified hotspots.*

KEYWORDS

Cholera, Geospatial analysis, Water, Sanitation and Hygiene (WASH), unregulated premises, Minna metropolis

I. INTRODUCTION

Cholera remains a major public health challenge in low- and middle-income countries. The ongoing seventh pandemic, caused by toxigenic *Vibrio cholerae*, has affected more than forty countries since 1961 and is transmitted mainly through the faecal-oral route via contaminated food and water, causing acute watery diarrhoea that can lead to death within hours if untreated. The World Health Organization estimates between 1.3 and 4.0 million cholera cases and 21,000 to 143,000 deaths annually worldwide, with the true burden considered higher because of under-reporting (World Health Organization, 2024). Within the WHO African Region, more than 2.7 million cases and over 63,000 deaths were reported across forty-four countries between 2000 and 2023, with deficiencies in water, sanitation and hygiene (WASH) consistently identified as the dominant modifiable risk factors.

Nigeria carries one of the highest cholera burdens in Africa. Major epidemics in 1991, 2010, 2018 and 2024 recorded case fatality ratios of up to 12.9%, well above the WHO target of below 1%, and Nigeria accounted for nearly seventy percent of cholera cases reported in the African Region in 2024, with outbreaks concentrated during the rainy season when flooding, overcrowding and inadequate waste management facilitate transmission (Nigeria Centre for Disease Control and Prevention, 2024). Niger State has experienced repeated outbreaks, including one that began in Gurara Local Government Area in May 2021, and another that originated in Shiroro Local Government Area in July 2025 and spread to six local government areas including Chanchaga and Bosso, which together form Minna metropolis, resulting in thirteen deaths and over 236 hospitalisations.

Minna metropolis has undergone rapid, largely unplanned urban expansion, with built-up area increasing by nearly 2000% between 1972 and 2015 and leaving many peri-urban communities without adequate roads, piped water, drainage and waste management facilities. This growth has also increased the number of informal commercial premises, including roadside food vendors, open markets, unregistered eateries and abattoirs, which often lack potable water, hand washing facilities and effective waste disposal, while discharging untreated effluent into nearby water bodies and creating conditions favourable for *Vibrio cholerae* transmission. A statistical analysis of thirteen African countries found that improved water supply reduced cholera risk by 4.2 to 84.1%, while improved sanitation reduced risk by 9.8 to 68.9%, and attributed persistent transmission to structural poverty, rapid urbanisation and weak waste management systems.

Recent advances in Geographic Information Systems and spatial analytical techniques, including the Getis-Ord G_i^* statistic developed by Getis and Ord (1992) to detect statistically significant local spatial clusters, have improved the understanding of cholera transmission by identifying disease hotspots and environmental risk factors in settings such as Ile-Ife and Ondo State, Nigeria. A geospatial study in Ile-Ife found that eighteen of forty-four waste dump sites, seven of eighteen markets and two of thirty-six abattoirs were located close to historical cholera cases, demonstrating the usefulness of GIS in identifying environmental hotspots and premises with potential cholera risk. Similarly, geospatial analysis of cholera patterns in Nigeria has demonstrated the presence of spatial hotspots and the importance of environmental and socioeconomic conditions in understanding the distribution of cholera. However, evidence on the spatial relationship between environmental health conditions and cholera risk in unregulated commercial premises in Minna metropolis remains limited. Because these premises are not routinely subjected to formal environmental health

inspection, their potential contribution to conditions that facilitate cholera transmission has not been adequately documented. Furthermore, Limited studies have applied geospatial techniques to assess the relationship between WASH conditions, environmental health hazards and cholera occurrence in unregulated premises within Minna metropolis.

The objective of this study was therefore to conduct a geospatial assessment of WASH and environmental health factors associated with cholera occurrence in selected unregulated premises in Minna metropolis, Niger State, Nigeria. Specifically, the study assessed water supply sources and sanitation practices, identified environmental health risk factors associated with cholera occurrence, examined the spatial distribution of cholera cases in relation to these factors, and assessed the awareness and compliance of premises operators with applicable regulations.

II. MATERIALS AND METHODS

A. Study Area:

The study was conducted in Minna metropolis, the capital city of Niger State, Nigeria, comprising Chanchaga and Bosso Local Government Areas, situated between latitudes $9^{\circ}31'20''\text{N}$ and $9^{\circ}41'27''\text{N}$ and longitudes $6^{\circ}24'59''\text{E}$ and $6^{\circ}37'42''\text{E}$. Chanchaga Local Government Area covered approximately 72 to 73.4 km^2 , while Bosso Local Government Area, characterised by peri-urban expansion, extended over approximately 1,592 km^2 . The metropolitan population exceeded 900,000 at the time of the study, having grown from 304,113 in 2007.

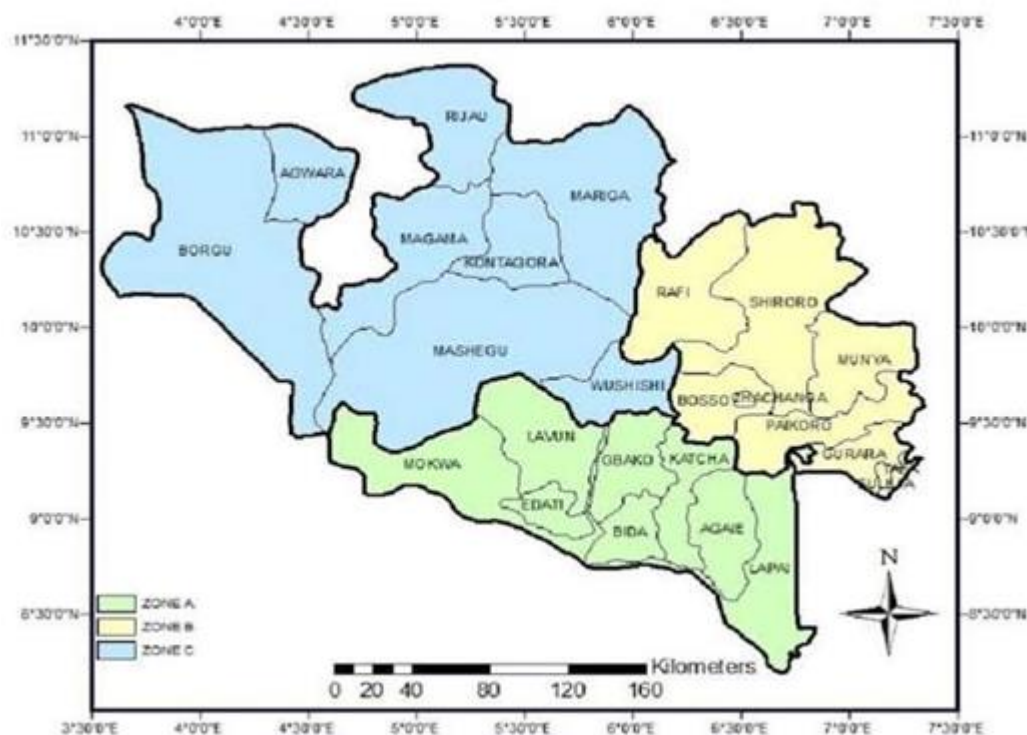


Figure 1: Map of the study area

B. Sample size and sampling design:

The study used a descriptive cross-sectional design with a geospatial component. Primary WASH and environmental health data were collected from unregulated commercial premises, while secondary cholera records were integrated into a GIS. The study covered Chanchaga and Bosso LGAs. Using Cochran's (1977) formula and finite population correction, a minimum sample of 270 was obtained from approximately 910 eligible premises. Convenience sampling was used, and data from 254 premises were analysed.

C. Sample collection and treatment:

Primary data were collected using a structured questionnaire and observational checklist on WASH practices and environmental health conditions. GPS coordinates and observed conditions were recorded during field observations in May and June 2025. Secondary cholera data for 2020–2025 were obtained from Niger State Ministry of Health surveillance reports and compiled at LGA level. Ethical approval and written informed consent were obtained before data collection.

D. Statistical data analysis:

Quantitative data were coded and analysed using SPSS. Frequencies and percentages summarised main study variables. Chi-square tests were used at the 0.05 significance level to assess differences in WASH practices between Chanchaga and Bosso and associations between environmental health risk factors and reported cholera occurrence.

III. RESULTS AND DISCUSSION

Water Supply Sources and Sanitation Practices in Selected Unregulated Premises: Of the 254 respondents surveyed, 152 (59.8%) were male and 102 (40.2%) females. Respondents aged 40 to 49 years constituted the largest age group, with 76 (29.9%). Open market shops accounted for 78 (30.7%) of sampled premises, followed by roadside food vending points with 59 (23.2%), unregistered eateries and water vending points with 51 (20.1%) each, and slaughterhouses with 15 (5.9%). Protected wells were the leading primary water source, reported by 67 (26.4%) respondents, followed by unprotected wells (45, 17.7%) and sachet or bottled water (43, 16.9%). Only 21 (8.3%) relied on public or piped water supply. Unprotected wells, vendors or tankers, and surface water combined accounted for 95 premises (37.4%). Water was stored in covered containers by 118 (46.5%) respondents, uncovered containers by 60 (23.6%), and overhead tanks by 51 (20.1%).

Open dumping within or around premises was the leading waste disposal method, reported by 78 (30.7%) respondents, followed by dumping into drains or water bodies (52, 20.5%) and formal government or private collection (51, 20.1%). No toilet facility was available in 102 (40.2%) premises, where respondents relied on open defecation, while 90 (35.4%) used pit latrines and 62 (24.4%) had water closets. Hand washing facilities with both water and soap were available in 51 (20.1%) premises, water alone in 178 (70.1%), and neither in 25 (9.8%). Although 203 (79.9%) premises were reported to be cleaned daily, 51 (20.1%) were not cleaned daily.

Table 1: socio-demographic characteristics and water/sanitation profile of surveyed premises
(n = 254)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	152	59.8
	Female	102	40.2
Premises Category	Open market shop	78	30.7
	Roadside food vending point	59	23.2
	Unregistered eatery	51	20.1
	Water vending point	51	20.1
	Slaughterhouse	15	5.9
Primary Water Source	Protected well	67	26.4
	Unprotected well	45	17.7
	Sachet/bottled water	43	16.9
	Water vendor/tanker	33	13.0
	Borehole	28	11.1
	Public/piped water supply	21	8.3
	Surface water	17	6.7
Toilet Facility	No facility (open defecation)	102	40.2
	Pit latrine	90	35.4
	Water closet	62	24.4

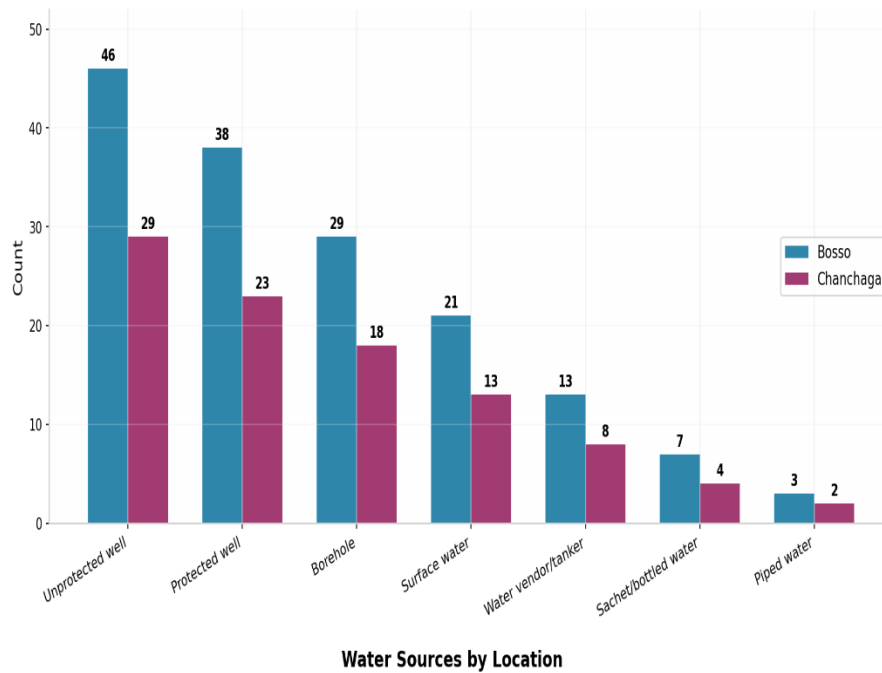


Figure. 2: distribution of water sources by Local Government Area (Chanchaga Vs Bosso)

Environmental Health Risk Factors Associated with Cholera Occurrence: Premises located near an open drainage channel accounted for 203 (79.9%), while 178 (70.1%) were located near a waste dumpsite. The observational checklist corroborated these findings, with visible solid waste accumulation recorded in 167 (65.7%) premises and flies, rodents or other disease vectors observed in 147 (57.9%). 168 (66.1%) surveyed premises reported at least one cholera case. Cross-tabulation showed that unsafe water sources, including unprotected wells, vendors and surface water, were associated with higher cholera reporting (Table 2). Among premises using unsafe sources, 99 of 137 (72.3%) recorded high cholera cases, compared with 25 of 117 (21.4%) among those using safe sources ($\chi^2 = 68.42$, $p < 0.001$). Open dumping or drainage disposal recorded 134 high-case premises out of 179 (74.9%), compared with 18.6–20.0% for other disposal methods ($\chi^2 = 82.15$, $p < 0.001$). Unsatisfactory sanitary conditions were also associated with higher cholera reporting, with 106 of 171 (62.0%) premises recording high cases compared with 21.7% of premises with satisfactory conditions ($\chi^2 = 45.67$, $p < 0.001$). The null hypothesis was therefore rejected. There was no significant difference between Chanchaga and Bosso in water source, waste disposal method or toilet facility type ($\chi^2 = 11.323$, $p = 0.079$; $\chi^2 = 6.164$, $p = 0.187$; $\chi^2 = 0.257$, $p = 0.879$, respectively).

Table 3 and Figure 3 shows that Magama recorded the highest cumulative cholera burden in Niger State between 2020 and 2025, with 510 cases, followed by Bosso (483), Mokwa (422) and Chanchaga (343). The year 2021 accounted for the largest share of cases across most Local Government Areas. Within Minna Metropolis, the Getis-Ord G_i^* analysis of the 254 geo-referenced WASH and environmental risk points showed that poor WASH conditions were not randomly distributed. A significant hot spot was identified around Minna, Minna South and the David Mark Road/Maitunbi corridor ($G_i^* z \approx +0.87$, $p = 0.048$), while the Bosso/Tutugo/Korpkpa Tutugo corridor showed a significant cold spot ($G_i^* z = -1.155$, $p = 0.001$). The choropleth map (Fig. 4) showed that premises with 16–25 and ≥ 26 reported cases were concentrated mainly in the southern and river-adjacent parts of Bosso and Chanchaga LGAs. The spatial distribution of the 254 geolocated premises (Fig. 5) showed greater concentrations of hazardous premises in Bosso, southern Minna, Matumbi, Minna Central and Minna South, with the Bosso/Tutugo/Korpkpa Tutugo corridor corresponding to the identified cold spot.

Table 2: chi-square test results for WASH practices, cholera cases and operator awareness/compliance

Variable Tested	χ^2 value	p-value	Decision
Water source $\times$ Location (LGA)	11.323	0.079	Not significant
Waste disposal method $\times$ Location (LGA)	6.164	0.187	Not significant
Toilet facility $\times$ Location (LGA)	0.257	0.879	Not significant
Water source $\times$ Cholera cases	68.42	$p < 0.001$	Significant
Waste disposal method $\times$ Cholera cases	82.15	$p < 0.001$	Significant
Sanitary condition $\times$ Cholera cases	45.67	$p < 0.001$	Significant
Awareness $\times$ Compliance	14.87	0.0001	Significant
Awareness of hygiene standards $\times$ Hand washing compliance	18.42	$p < 0.001$	Significant

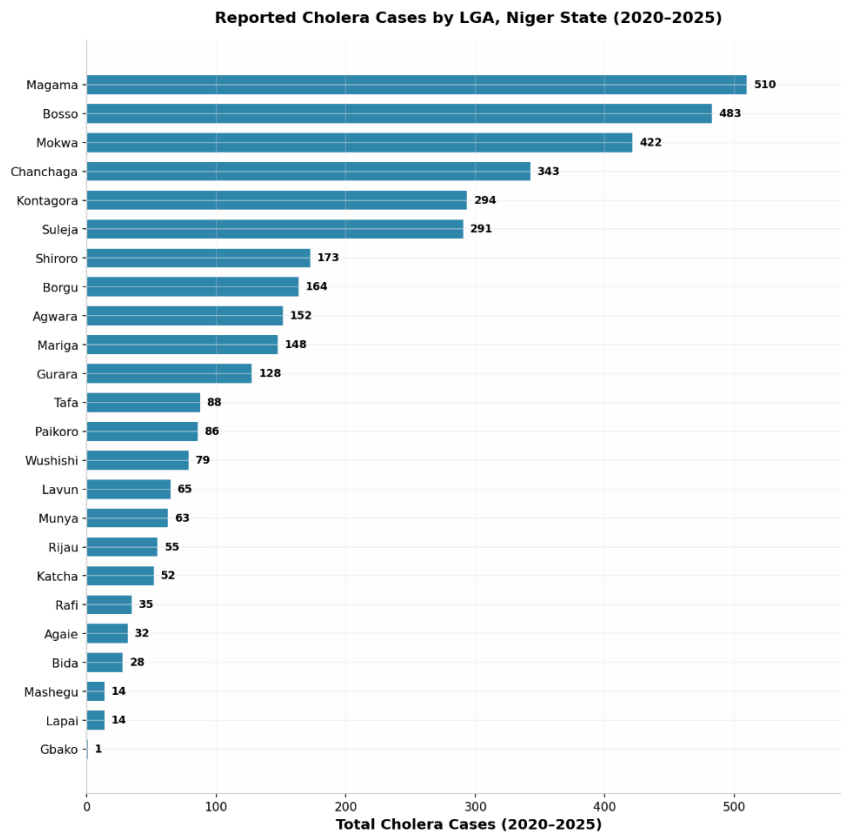


Figure. 3: Yearly distribution of reported cholera cases by Local Government Area, Niger State (2020-2025)

Table 3: reported cholera cases by Local Government Area, Niger State (2020-2025), leading six LGAs

LGA	2020	2021	2022	2023	2024	2025	Total
Magama	0	442	0	2	51	15	510
Bosso	4	348	0	0	14	117	483
Mokwa	0	276	23	62	35	26	422
Chanchaga	0	109	8	6	26	194	343
Kontagora	0	293	0	0	1	0	294
Suleja	1	190	21	12	62	5	291

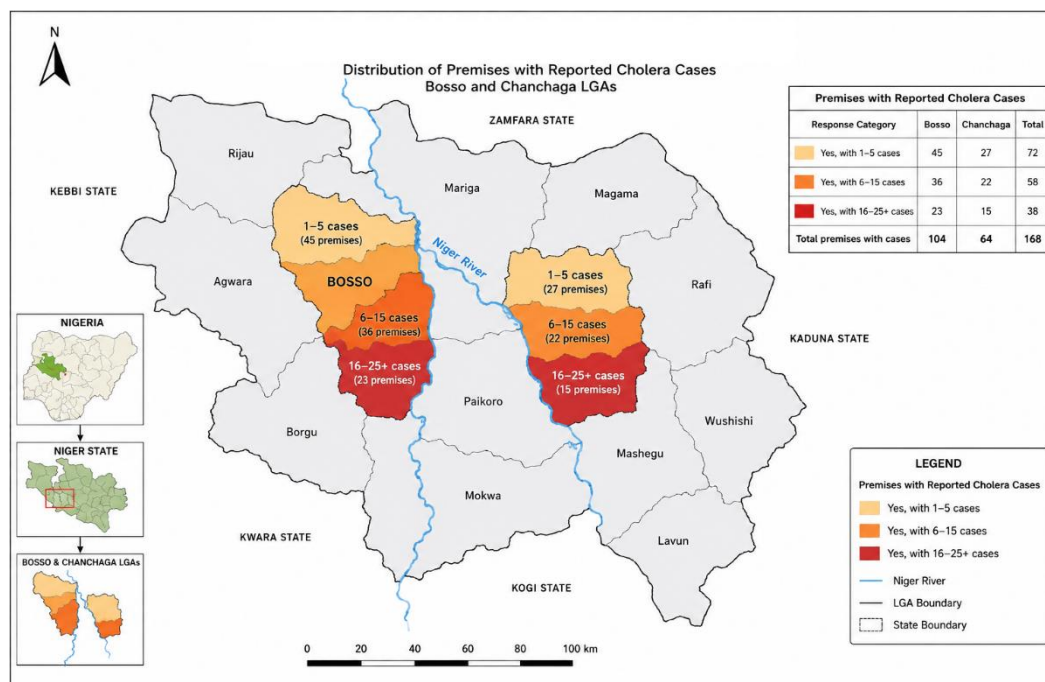


Figure. 4: choropleth distribution of premises with reported cholera cases across Bosso and Chanchaga LGAs

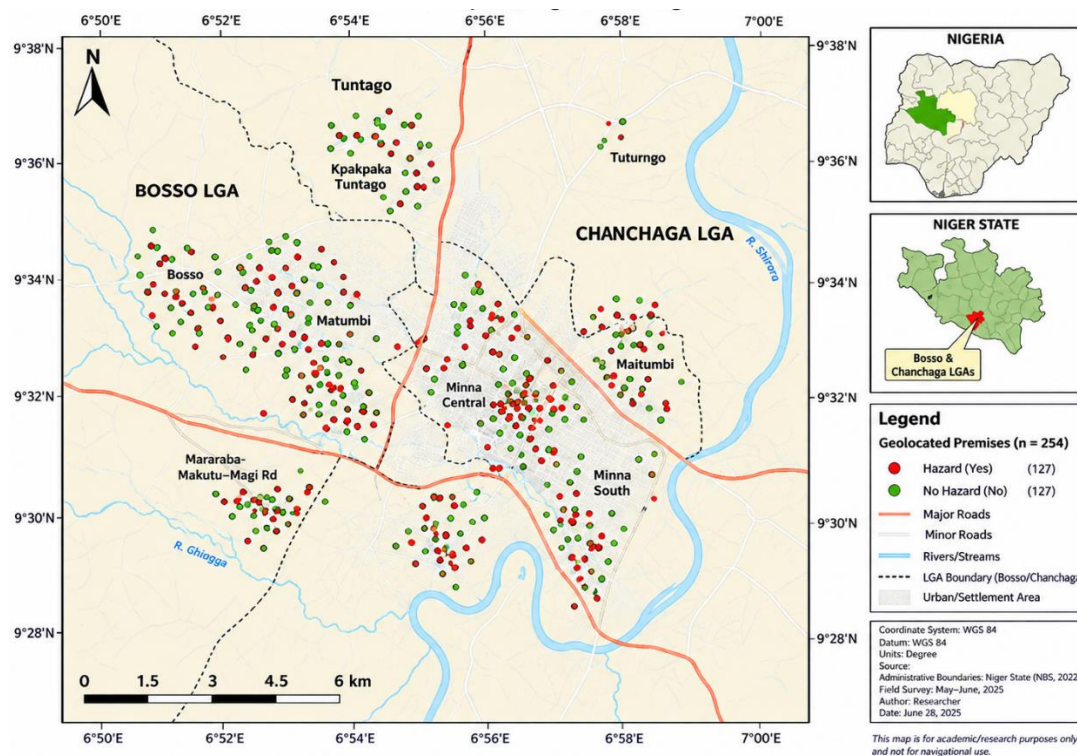


Figure. 5: point map of 254 field-surveyed premises by WASH/environmental hazard status

Level of Awareness and Compliance of Operators with WASH Regulations: Awareness of environmental health regulations among operators was generally high. A total of 203 (79.9%) were aware of hygiene standards, 178 (70.1%) had received training or information, and 151 (59.4%) were aware of registration requirements. Compliance was lower, with only 51 (20.1%) premises having functional hand washing facilities with water and soap, 51 (20.1%) using proper waste disposal methods, and 10 (3.9%) treating water before use. Among operators with high awareness, 68 (42.5%) demonstrated high compliance compared with 18 (19.1%) among those with low awareness, and the association was statistically significant ($\chi^2 = 14.87$, $p = 0.0001$). Awareness of hygiene standards was also significantly associated with hand washing compliance ($\chi^2 = 18.42$, $p < 0.001$). The null hypothesis of no relationship between awareness and compliance was therefore rejected.

This study assessed the geospatial distribution of WASH and environmental health factors associated with cholera outbreaks in selected unregulated premises in Minna Metropolis. The findings reported a high level of WASH problems within the 254 studied premises. Only 21 (8.3%) used a public or piped water supply, while 95 (37.4%) used unprotected wells, street vendors/tanker trucks, or surface water. In addition, 102 premises had no toilet facilities, while 78 used open dumping. These findings compare well with those reported in the study conducted in Ile-Ife in 2025, which showed deficits of 89%, 90% and 94% in access to potable water supply, adequate sanitary facilities and safe solid waste disposal, respectively.

Findings from a Minna-based study and this study reported untreated well water, improper refuse disposal and poor sanitary conditions as potential cholera risk factors (Mamman et al., 2024). These findings are consistent and suggest that inadequate WASH may be an important environmental factor in cholera outbreaks in Nigerian communities.

Sources of contaminated water and poor sanitary conditions were significantly associated with self-reported cholera incidence ($\chi^2 = 68.42$, $p < 0.001$). Among premises using unsafe water sources, 99 (72.3%) reported a higher frequency of cholera incidence, compared with 25 (21.4%) among those using safe sources. Improper waste disposal, including open dumping or drainage disposal, showed a similar pattern, with 134 (74.9%) premises reporting a higher frequency of cholera incidence ($\chi^2 = 82.15$, $p < 0.001$). These findings agree with Salubi and Elliott (2021), who reported that water supply sources and refuse disposal methods are important factors in the spatial distribution of cholera across Nigeria. They also agree with Olanrewaju and Adepoju (2017), who identified a relationship between cholera incidence and environmental risk factors in Ile-Ife through GIS analysis.

A significant WASH hazard hotspot was identified around Minna and Minna South, including the area from David Mark Road to the Maitunbi corridor ($G_i^* z = +0.87$, $p = 0.048$). Premises reporting 16–25 and more than 26 cholera cases were largely clustered around the river and southern parts of Bosso and Chanchaga. This finding is consistent with the spatial clustering of cholera reported across Nigeria by Salubi and Elliott (2021) and the geographical relationship between cholera cases and environmental risk factors identified in Ile-Ife by Olanrewaju and Adepoju (2017).

A wide disparity was observed between knowledge and practice. Although 203 (79.9%) operators were aware of hygienic practices, only 51 (20.1%) premises had functional hand washing facilities with soap and water. Water treatment before use was practised in only 10 (3.9%) premises. High awareness was significantly associated with compliance ($\chi^2 = 14.87$, $p = 0.0001$).

This finding is consistent with Barnabas et al. (2024), who reported that food safety information and education were associated with better knowledge, although gaps remained in some food safety practices. Similarly, Ibrahim et al. (2023) found that personal hygiene knowledge among street food vendors and canteen food handlers in Kano was generally poor or fair and recommended stronger training and regulatory enforcement. The present study further shows that awareness alone may be insufficient to achieve adequate hygiene practices without supportive interventions.

IV. CONCLUSION

This study found inadequate WASH conditions in many unregulated premises in Minna Metropolis, including unsafe water sources, poor waste disposal, inadequate sanitation and limited hand washing facilities. These conditions were present in both Chanchaga and Bosso and were significantly associated with cholera occurrence. GIS analysis identified a significant WASH hazard hot spot around Minna, Minna South and the David Mark Road/Maitunbi corridor. A gap was also found between operators' awareness and compliance with hygiene requirements. The study recommends targeted WASH interventions, routine inspection of unregulated premises, improved waste management, stronger monitoring of water vendors and continued investment in water and sanitation infrastructure.

V. DECLARATIONS

A. *Ethical Approval:*

Ethical approval for this study was obtained from the relevant institutional research ethics committee and the Niger State Ministry of Health prior to data collection. Written informed consent was obtained from all participating operators, and secondary cholera case data were anonymised and treated confidentially.

B. *Disclaimer (Artificial Intelligence):*

The authors confirm that no generative artificial intelligence tool was used to generate original data, analysis, or scientific conclusions presented in this manuscript.

C. *Declaration of Conflict of Interest:*

The authors affirm that no conflict of interest exists in relation to this study.

D. *Declaration of Data Availability:*

The data supporting this study can be made available by the corresponding author upon reasonable request.

REFERENCES

- [1] Adeolu, AT; Opasola, AO; Salami, OO; Iyanda, AY; Omenta, RC (2019). Sanitary status and compliance with the standard slaughter practices in Karu Abattoir Abuja Municipal Area Council of the FCT, Nigeria. *Int. J. Curr. Innov. Adv. Res.* 2(2): 1–14.
- [2] Awere-Duodu, A; Ntim, OK; Donkor, ES (2025). *Vibrio cholerae* in water environments: A systematic review and meta-analysis. *Environ. Microbiol. Rep.* 17(3): e70103. DOI: <https://doi.org/10.1111/1758-2229.70103>.
- [3] Barimah, AJ; Nketiah, YB; David, AB; Oppong, PR; Osei, J; Gyamfua, BO (2026). Food safety and hygiene practices utilized by native street food vendors in Yamfo Community, Ghana and its impact on consumer health. *Sci. Rep.* 16(1): 8367. DOI: <https://doi.org/10.1038/s41598-026-38241-z>.
- [4] Barnabas, B; Bavorova, M; Madaki, MY; Kächele, H (2024). Food safety knowledge, attitudes, and practices of food vendors participating in Nigeria's school feeding program. *J. Consum. Prot. Food Saf.* 19: 199–212. <https://doi.org/10.1007/s00003-023-01476-3>.
- [5] Getis, A; Ord, JK (1992). The analysis of spatial association by use of distance statistics. *Geogr. Anal.* 24(3): 189–206.
- [6] Girotto, CD; Behzadian, K; Musah, A; Chen, AS; Djordjevic, S; Nichols, G; Campos, LC (2024). Analysis of environmental factors influence on endemic cholera risks in sub-Saharan Africa. *Sci. Total Environ.* 926: 171896. DOI: <https://doi.org/10.1016/j.scitotenv.2024.171896>.
- [7] Ibrahim, UM; Garba, RM; Jalo, RI; Tsiga-Ahmed, FI; Musa, A; Karkarna, MZ; Yusuf, MA; Jibo, AM; Umar, ML (2023). Knowledge of personal hygiene among street food vendors and canteen food handlers in Kano: A mixed methods study. *Niger. Med. J.* 64(3): 337–351. <https://doi.org/10.60787/nmj.v64i3.165>.
- [8] Idowu, OO; Bako, AI; Aduloju, OTB (2020). Analysis of the trend of peri-urban development in Minna, Niger State. *J. Geogr. Inf. Syst.* 12: 411–431. DOI: <https://doi.org/10.4236/jgis.2020.125025>.
- [9] Izah, SC; Etim, NG; Alaka, OO; Nwachukwu, BC; Joshua, G (2024). Public health interventions for cholera control and prevention: Water, sanitation, and hygiene (WASH) perspective. *Greener J. Epidemiol. Public Health.* 12(1): 1–15. DOI: <https://doi.org/10.15580/gjeph.2024.1.102024145>.
- [10] Koua, EL; Moussana, FH; Sodjinou, VD; Kambale, F; Kimenyi, JP; Diallo, S; Okeibunor, J; Gueye, AS (2025). Exploring the burden of cholera in the WHO African region: Patterns and trends from 2000 to 2023 cholera outbreak data. *BMJ Glob. Health.* 10: e016491. DOI: <https://doi.org/10.1136/bmjgh-2024-016491>.
- [11] Mamman, AA; Kuti, IA; Yisa, MK; Idris, IM (2024). Analysis of the risk factors to cholera outbreaks in parts of Minna, Niger State. *Environ. Technol. Sci. J.* 15(2): 28–36. <https://doi.org/10.4314/etsj.v15i2.4>.
- [12] Mbala-Kingebeni, P; Vogt, F; Miwanda, B; Sundika, T; Mbula, N; Pankwa, I; Lubula, L; Vanlerberghe, V; Magazani, A; Afoumbom, MT; Muyembe-Tamfum, JJ (2021). Sachet water consumption as a risk factor for cholera in urban settings: Findings from a case-control study in Kinshasa, Democratic Republic of the Congo during the 2017–2018 outbreak. *PLOS Negl. Trop. Dis.* 15(12): e0009942.

- [13] Ngosa, W; Imamura, T; Mbewe, N; Seriki, J; Nzila, O; Mfunne, F; Zulu, G; Mulando, C; Chiluba, T; Miyanda, L; Phiri, A; Sichone, L; Mwape, G; Mulenga, K; Chileshe, C; Mabuku, N; Banda, D; Yan, F; Kamigaki, T; Chilengi, R; Sinyange, N (2025). Geospatial analysis of cholera outbreak in Lusaka, Zambia, between 2023 and 2024. *Trop. Med. Health.* 53: 42. DOI: <https://doi.org/10.1186/s41182-025-00718-4>.
- [14] Ngwa, MC; Ihekweazu, C; Okwor, T; Yennan, S; Williams, N; Elimian, K; Karaye, NY; Bello, IW; Sack, DA (2021). The cholera risk assessment in Kano State, Nigeria: A historical review, mapping of hotspots and evaluation of contextual factors. *PLOS Negl. Trop. Dis.* 15(1): e0009046. DOI: <https://doi.org/10.1371/journal.pntd.0009046>.
- [15] Nigeria Centre for Disease Control and Prevention (2024). Cholera situation report (Epidemiological Week 1–52, 2024). NCDC. <https://ncdc.gov.ng>.
- [16] Olanrewaju, OE; Adepoju, KA (2017). Geospatial assessment of cholera in a rapidly urbanizing environment. *J. Environ. Public Health.* 2017: 6847376. DOI: <https://doi.org/10.1155/2017/6847376>.
- [17] Ovuru, KF; Izah, SC; Ogidi, OI; Imarhiagbe, O; Ogwu, MC (2023). Slaughterhouse facilities in developing nations: Sanitation and hygiene practices, microbial contaminants and sustainable management system. *Food Sci. Biotechnol.* 33(3): 519–537. DOI: <https://doi.org/10.1007/s10068-023-01354-3>.
- [18] Salubi, E.A., Elliott, S.J. Geospatial analysis of cholera patterns in Nigeria: findings from a cross-sectional study. *BMC Infect Dis* 21, 202 (2021). DOI: <https://doi.org/10.1186/s12879-021-05894-2>.
- [19] Tuglo, LS; Agordoh, PD; Tekpor, D; Pan, Z; Agbanyo, G; Chu, M (2021). Food safety knowledge, attitude, and hygiene practices of street-cooked food handlers in North Dayi District, Ghana. *Environ. Health Prev. Med.* 26: 54. DOI: <https://doi.org/10.1186/s12199-021-00975-9>.
- [20] World Bank (2021). Improving water supply, sanitation and hygiene services in Nigeria. World Bank Press Release, 25 May 2021. <https://www.worldbank.org/en/news/press-release/2021/05/25/improving-water-supply-sanitation-and-hygiene-services-in-nigeria>.
- [21] World Health Organization (2024). Cholera: Fact sheet. WHO. <https://www.who.int/news-room/fact-sheets/detail/cholera>.