



Geospatial Assessment of the Spatial Distribution of Water, Sanitation and Hygiene (WASH) Facilities among Households in Ife Central Local Government Area, Osun State, Nigeria

Oghomwenyemen Ellen Omorodion¹, Ehisiemhen Nicholas Osabhohien², Adeleke Oluwafemi Adetola², Renner Moses Adeolu¹, Hassan Ahmad Ahmad³, Andrew Imade⁴, Alao Feyishayo Atinuke⁶, Abubakar A. Dimari³, Gbenle Akeem Olalekan¹, Imran Badirat Olajumoke¹, Adamu Ismaila¹, Mba Tochukwu Williams⁴, Aluma Collins Chinecherem⁵, Martins Enehireha Abhulimen⁷, Akuh Charles Jamah², Gbenga Gideon Oyetoro², and Audu Sadiq Dauda¹

¹Centre for Space Life Sciences, University of Ibadan, Ibadan, Nigeria.

²Advance Space Technology Application Laboratory, South-West (Copine), Obafemi Awolowo University Campus, Ile-Ife, Osun State, Nigeria.

³Centre for Geodesy and Geodynamics, Toro.

⁴United Nations African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E), Ile-Ife.

⁵Advanced Unmanned Aerial Vehicle (AUAV), Abakaliki.

⁶National Space Research and Development Agency, FCT, Abuja

⁷Advanced Aerospace Engineering Labouratory, Oka Akoko, Ondo State

DOI: <https://doi.org/10.47772/IJRISS.2026.100800586>

Received: 28 August 2026; Accepted: 02 September 2026; Published: 12 September 2026

ABSTRACT

Water, sanitation, and hygiene (WASH) facilities are essential to public health, yet household-level coverage may vary substantially within the same local government area. Aggregate survey statistics can describe overall coverage but may not reveal the geographic concentration of facility gaps. This study assessed the spatial distribution of household WASH facilities in Ife Central Local Government Area (LGA), Osun State, Nigeria, using a descriptive cross-sectional design combined with geospatial mapping and exploratory statistical comparison. A multistage sample of 425 households, comprising 84 households in less-dense settlements and 341 in dense settlements, was selected using a fishnet-grid sampling framework developed from building-footprint imagery in ArcGIS 10.8. Geographic coordinates and facility attributes for household drinking-water sources, sanitation facilities, and handwashing stations were collected during field visits using KoboCollect, cleaned, and mapped in ArcGIS using the WGS 1984 UTM Zone 31N coordinate system.

Among sampled households, piped water into the dwelling was the most frequently reported drinking-water source (40.9%), followed by protected wells (19.8%) and sachet water (13.2%). Sanitation facilities were dominated by flush-to-soakaway systems (47.3%) and flush-to-septic-tank systems (30.4%), while handwashing facilities with water and soap accounted for 83.5% of the sample. Unprotected wells, facilities without sanitation, open or unlined pit latrines, and water-only handwashing stations were numerically more frequent in dense settlements, and exploratory chi-square comparisons indicated that this association was statistically significant for sanitation and handwashing facilities ($p < 0.05$) but not for drinking-water source ($p > 0.05$); these tests should be interpreted cautiously given small expected cell counts in several categories. Geospatial mapping identified localised concentrations, including unprotected wells around Akarabata. These findings describe the spatial distribution of facilities among the households sampled and should not be read as a complete inventory of WASH infrastructure across the LGA. The study illustrates the value of combining geospatial mapping with descriptive and exploratory statistical comparison for identifying location-specific

WASH inequities and provides an evidence base for targeting improvements in water supply, sanitation, and hygiene facilities in support of Sustainable Development Goal 6.

Keywords: WASH facilities; geospatial mapping; GIS; spatial distribution; Ife Central; Osun State; Nigeria

INTRODUCTION

Background and Problem Statement

Water, sanitation, and hygiene (WASH) are central to public health and to the achievement of the Sustainable Development Goals. Adequate household WASH encompasses access to safe drinking water, hygienic sanitation facilities, and practices that support personal hygiene and wellbeing (World Health Organization [WHO], 2023). Adequate WASH provision is also fundamental to disease prevention, health promotion, and poverty reduction (WHO, 2020). Where WASH facilities are inadequate, exposure to waterborne and faeco-oral diseases such as diarrhoea, cholera, and typhoid increases, particularly in low- and middle-income settings (WHO, 2019).

In Nigeria, the 2018 Water, Sanitation and Hygiene National Outcome Routine Mapping (WASH-NORM) Survey found that about 73.4% of households had access to improved drinking-water sources and 57.4% used improved sanitation facilities, while only 22.1% had fixed handwashing stations with both water and soap (Federal Ministry of Water Resources & National Bureau of Statistics, 2018). More recently, the 2023–24 Nigeria Demographic and Health Survey reported that 9.0% of children under five experienced diarrhoea in the two weeks preceding the survey, highlighting the continuing importance of WASH improvement (Federal Ministry of Health and Social Welfare, National Population Commission, & ICF, 2024).

Conventional household surveys are useful for estimating aggregate coverage (Deaton, A. (2019), but they may conceal the spatial clustering of inadequate facilities. Geospatial mapping provides an opportunity to visualise where facilities are located, where facility gaps occur, and how these gaps relate to settlement patterns (Yu, W., Bain, R. E., Yu, J., Alegana, V., Dotse-Gborgbortsi, W., Lin, Y., & Wright, J. A. 2021). Previous studies have used GIS to map household access to water and sanitation and to identify spatial inequalities in WASH provision (Ayeni, A. O., Soneye, A. S. O., & Balogun, I. I. 2009, Ayeni, A. O., & Soneye, A. S. O. 2011, Pullan, R. L., Freeman, M. C., Gething, P. W., & Brooker, S. J. 2014, Awodumi, O., & Olatubara, C. O. 2023). Geospatial approaches, including formal spatial-statistical techniques where data permit, have also been identified as cost-effective for planning, monitoring, and evaluating WASH interventions in resource-limited settings (Fletcher-Lartey, S. M., & Caprarelli, G. 2016, Zhou, X. N., Xin-Yu, F., & Shang, X. 2018).

The present study therefore mapped and described the spatial distribution of household WASH facilities in Ife Central LGA by integrating georeferenced facility information with household survey attributes in a GIS environment, and examined whether facility distributions differed by settlement density using descriptive comparison and exploratory chi-square tests. The study focused on the distribution of drinking-water sources, sanitation facilities, and handwashing facilities across different settlement-density contexts.

Objective of the Study

The objective of the study was to assess the spatial distribution of water, sanitation, and hygiene (WASH) facilities among households in Ife Central Local Government Area, Osun State, Nigeria.

Study Area

The study was conducted in Ife Central Local Government Area of Osun State, south-western Nigeria. The LGA is located at approximately latitude 7°33'0" N and longitude 4°32'0" E.

The estimated 2025 population is about 217,100, with a population density of roughly 1,600 -1,950 persons/km², and an area of approximately 111–136 km² (National Population Commission, 2022). The area lies within the tropical rainforest zone, with a rainy season from March to October and a dry season from November to February. Annual rainfall is reported at about 1,200–1,500 mm, while temperatures range from

approximately 21°C to 34°C. The LGA is drained by the River Osun, River Oba, and smaller streams and seasonal creeks, and its groundwater resources are associated with basement-complex and sedimentary aquifers that support wells and boreholes.

Ife Central contains both planned, relatively low-density settlements and more densely settled areas with varying income levels and sanitary conditions. This settlement structure provides an appropriate setting for examining spatial variation in household WASH provision and comparing the distribution of facilities across different settlement-density contexts.

LITERATURE REVIEW

WASH Access and Spatial Inequality

Adequate access to water, sanitation and hygiene (WASH) is essential for disease prevention, health promotion, and improved living conditions. Despite global progress in WASH provision, access remains uneven across regions and population groups. In Nigeria, the 2021 Water, Sanitation and Hygiene National Outcome Routine Mapping (WASHNORM) documented wide disparities in access to WASH services across states, geopolitical zones, rural and urban areas, and household wealth groups (Federal Ministry of Water Resources, National Bureau of Statistics, World Bank, & UNICEF, 2022). In Osun State, Fafunwa et al. (2017) assessed the status of WASH resources and hygienic practices in eight rural communities in Aiyedaade Local Government Area and reported substantial soil-transmitted helminthiasis among the study population, with an overall prevalence of 35.2%. The study also found low levels of knowledge, attitudes, and practices concerning soil-transmitted helminthiasis and highlighted the need to consider WASH conditions in strategies for controlling disease transmission. These findings demonstrate the importance of examining WASH conditions at local scales, where variations in access and service conditions may have important implications for public health.

Geospatial Approaches to WASH Assessment

Geographic Information Systems (GIS), remote sensing, Global Positioning System (GPS), and spatial analysis techniques provide valuable approaches for assessing WASH conditions because they enable the spatial distribution of WASH services to be examined alongside demographic, environmental, and infrastructural characteristics. In Nigeria, Ajisegiri et al. (2019) developed a geospatial model to map access to water and sanitation using geo-referenced, population-representative data from the 2015 National Water and Sanitation Survey and relevant geospatial covariates. The model generated estimates of seven water and sanitation indicators at a spatial resolution of 1×1 km and revealed substantial geographical variation, including a pronounced urban–rural divide in access to improved and basic water services and the concentration of improved sanitation in particular areas of the country.

At the household level, Mobolaji and Akinwumiju (2025) further demonstrated the application of spatial and non-spatial statistical approaches to examining WASH conditions and associated household characteristics in Nigeria. Using georeferenced Demographic and Health Survey data, the study examined household water, sanitation, and hygiene conditions and identified significant relationships between WASH conditions and factors including wealth, literacy, residence, and sex of household head. These studies demonstrate the feasibility and value of geospatial approaches for identifying geographical and household-level disparities in WASH provision. However, national-scale analyses may not adequately capture variations within individual local government areas or communities. Consequently, there remains a need for fine-scale, household-level geospatial assessments of WASH conditions in secondary urban centres such as Ife Central LGA.

Research Gap

Much Nigerian WASH research at the local-government level continues to rely on descriptive household survey statistics without georeferenced facility mapping, so aggregate coverage figures may conceal the neighbourhoods where facility deficiencies are concentrated. The present study addresses this gap by providing fine-scale, household-level geospatial evidence for Ife Central LGA specifically mapping household-level WASH facilities and examining their distribution across dense and less-dense settlement contexts.

METHODOLOGY

Study Design

A descriptive cross-sectional design was combined with geospatial mapping and exploratory statistical comparison to capture WASH indicators and facility locations at a single point in time across dense and less-dense settlements. The approach was designed to provide a spatially explicit snapshot of household WASH conditions for identifying facility gaps and priority locations, based on the sampled households rather than a complete census of WASH infrastructure in the LGA.

Sample Size and Sampling Technique

The minimum sample size was determined using Cochran's formula at a 95% confidence level, with $z = 1.96$, $p = q = 0.5$, and a 5% margin of error. This produced a base sample size of 384 households. Allowing for a 10% anticipated non-response rate gave a target of 426 households, of which 425 households were ultimately included in the analysis after cleaning.

A multistage sampling procedure was used. Residential areas were first classified into less-dense and dense settlement zones using building-footprint information derived from Sentinel-2 imagery accessed via Google Earth Engine (10 m spatial resolution; exact acquisition date not recorded during data extraction). A building density surface was generated in ArcGIS 10.8 using the Kernel Density tool applied to building point locations, producing a continuous raster (261 columns $\times$ 251 rows, cell size $\approx$ 61.7 m, in the GCS_WGS_1984 coordinate system; output values are expressed per square degree given the unprojected coordinate system, with a minimum of 0, maximum of 60,821,336, and a mean of approximately 4,793,626). The two settlement categories were distinguished by a manual classification break at a raster value of 5,920,633.425, separating less-dense (0–5,920,633.425) from dense (5,920,633.426–60,821,336) zones, and validated against field observations through ground-truthing.

A fishnet grid of 319.8 m $\times$ 353.2 m cells — distinct from the finer density raster grid — was then superimposed on the study area in ArcGIS 10.8 to provide an evenly distributed spatial sampling framework, generating 1,376 cells, of which 426 were randomly selected across the two density categories. Neighbourhoods were selected from the two settlement categories using simple random sampling, with household selection weighted by the spatial representation of the grid cells; where a selected grid cell contained multiple residential buildings, the specific household was chosen based on respondent availability. Fieldwork yielded 84 households from less-dense settlements and 341 from dense settlements.

Data Collection and Sources

Primary data consisted of geographic coordinates and non-spatial attributes of household drinking-water sources, sanitation facilities, and handwashing stations. Coordinates were captured during household visits using the KoboCollect mobile data-collection application. Facility attributes included facility type, physical condition, usage pattern, capacity, and maintenance status.

Data exported from KoboCollect were checked for coordinate accuracy, duplicate entries, geolocation errors, and coordinate-format consistency. The cleaned dataset was compiled in Microsoft Excel and exported as CSV for GIS processing. The administrative boundary of Ife Central LGA and other spatial datasets were integrated with the facility data.

Geospatial Processing and Mapping

ArcGIS 10.8 was used for spatial data processing, georeferencing, symbolisation, and thematic map production. The working coordinate system was WGS 1984 UTM Zone 31N. Household WASH facilities were represented as point features and symbolised according to facility type. Separate thematic maps were produced for drinking-water sources, sanitation facilities, handwashing facilities. The maps were interpreted visually to identify areas of apparent concentration, sparse provision, and facility deficiency; this visual mapping is descriptive and does not itself establish that any observed clustering is statistically significant, since it can also reflect the sampling design or the uneven number of households sampled in dense versus less-

dense areas.

Statistical Analysis

Descriptive frequencies and percentages were calculated for drinking-water source, sanitation facility, and handwashing facility categories, both overall and within each settlement-density stratum (less-dense, $n = 84$; dense, $n = 341$), to avoid the earlier practice of reporting only whole-sample percentages for subgroup comparisons. To assess whether facility-type distributions differed by settlement density, exploratory chi-square tests of independence were computed for each domain using the reported frequency counts. Because several categories had small expected cell counts, these results should be treated as indicative rather than confirmatory; Fisher's exact test or category collapsing would be preferable in a final analysis.

RESULTS AND DISCUSSION

Sample Distribution

A total of 425 households were analysed. Of these, 84 households (19.8%) were located in less-dense settlements, while 341 households (80.2%) were located in dense settlements. This sample describes the households visited during fieldwork; it is not a complete census of dwellings or WASH facilities in the LGA, and the settlement-density groups are of very different sizes, which is taken into account below by reporting within-group percentages and exploratory significance tests rather than raw counts alone.

Spatial Distribution of Drinking-Water Sources

Field mapping identified public taps/standpipes, piped water to yards and dwellings, tube wells and boreholes, protected and unprotected wells, bottled water, sachet water, and piped water obtained from neighbours. Among sampled households, public taps and standpipes were mapped mainly around Moreojaja and Iremo, where they functioned as shared communal sources. Direct piped connections were more frequently mapped in the developed parts of the study area that were sampled, while boreholes and wells were distributed across several neighbourhoods. Unprotected wells were concentrated around Akarabata among sampled households, representing a location-specific concern because of their greater potential contamination risk.

Table 1 shows that piped water into the dwelling was the most frequently reported drinking-water source overall (40.9%), followed by protected wells (19.8%) and sachet water (13.2%). Within settlement strata, piped water into the dwelling was reported by 45.2% of less-dense households compared with 39.9% of dense households, and unprotected wells were reported only among dense-settlement households (2.1% of that stratum). An exploratory chi-square test found no statistically significant association between settlement density and drinking-water source category ($\chi^2 = 7.65$, $df = 8$, $p = 0.47$), although several expected cell counts were below 5, so this result should be interpreted with caution and re-checked with a larger or recategorised dataset.

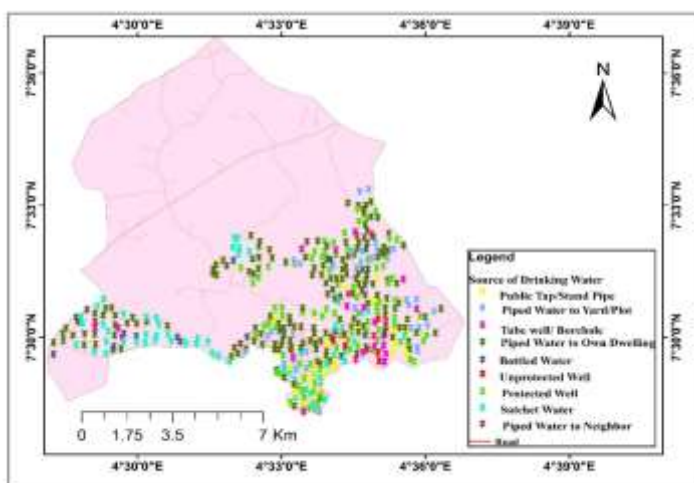


Figure 1: Spatial Distribution of Drinking Water Sources in Ife Central Local Government Area

(sampled households). Source: Author's analysis.

Spatial Distribution of Sanitation Facilities

Sanitation facilities mapped in the study area included pit latrines, flush toilets, and locations without a sanitation facility. Among sampled households, improved flush systems were more frequently mapped in developed areas, while inadequate sanitation conditions were concentrated in particular underserved locations. The mapping also identified locations where households reported no sanitation facility, relying on bushes or fields, as well as sanitation conditions linked with open drainage, both of which represent environmental and public-health concerns.

According to Table 1, flush-to-soakaway systems represented 47.3% of reported sanitation facilities overall, followed by flush-to-septic-tank systems (30.4%). Flush to an open drain accounted for 8.2%, pit latrines with slabs 4.7%, no facility/bush/field 4.0%, pit latrines without slabs/open pits 2.6%, and flush to pit latrine 1.4%.

The higher-risk categories — no sanitation facility and open or unlined pit latrines — were more frequent, in absolute terms, among dense-settlement households. Within strata, flush-to-septic-tank facilities were reported by 42.9% of less-dense households compared with 27.3% of dense households, while flush-to-soakaway facilities were similar across strata (46.4% vs. 47.5%). An exploratory chi-square test indicated a statistically significant association between settlement density and sanitation-facility category ($\chi^2 = 13.15$, $df = 6$, $p = 0.041$), though again with some small expected cell counts; this result is consistent with, but does not on its own establish causally, a link between settlement density and sanitation-facility type.

The very high reported share of flush-to-soakaway sanitation (47.3% overall) is notable given the infrastructural context typical of Nigerian secondary urban centres.

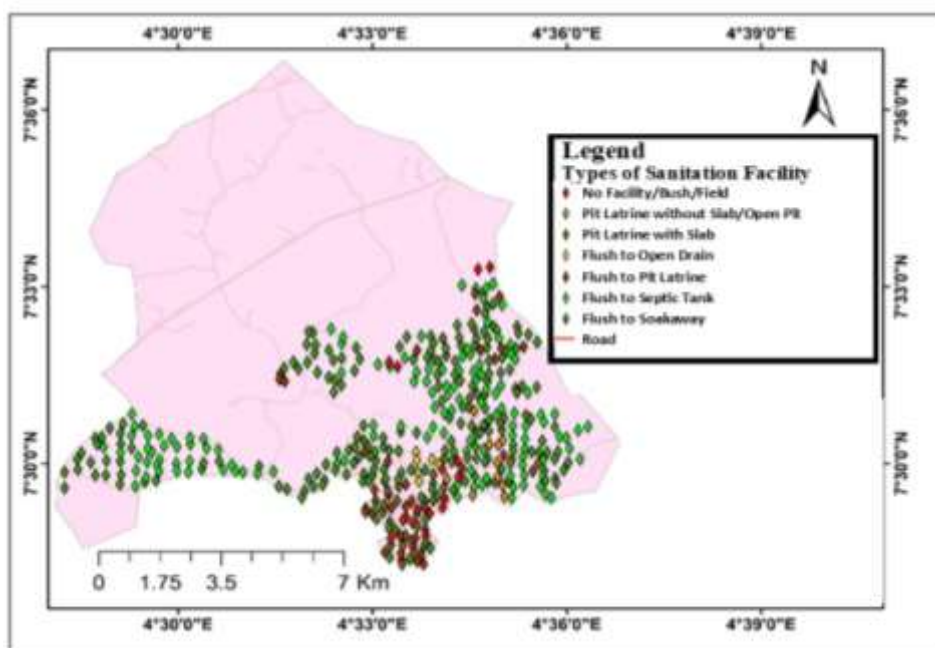


Figure 2: Spatial Distribution of Sanitation Facilities in Ife Central Local Government Area (sampled households). Source: Author's analysis.

Spatial Distribution of Handwashing Facilities

Handwashing facilities were assessed according to the availability of water, soap, ash, or hand sanitiser. Among sampled households, water-only facilities were present in several locations, while water-and-soap facilities were more common overall. Water combined with ash and hand-sanitiser facilities occurred in smaller numbers, and the most complete combination of water, soap, and sanitiser was uncommon.

Table 1 indicates that water-and-soap facilities accounted for 83.5% of households overall, followed by water-only facilities at 10.4%, hand sanitiser at 3.5%, water with ash at 1.9%, and other arrangements at 0.7%.

Within strata, water-and-soap facilities were reported by 75.0% of less-dense households compared with 85.6% of dense households, while water-only facilities were reported by 16.7% of less-dense households compared with 8.8% of dense households. An exploratory chi-square test found a statistically significant association between settlement density and handwashing-facility category ($\chi^2 = 14.50$, $df = 4$, $p = 0.006$), again subject to small-cell caveats. This indicates that the presence of a handwashing point does not necessarily imply that all components required for effective hand hygiene are consistently available, and that this varies with settlement density among the households sampled.

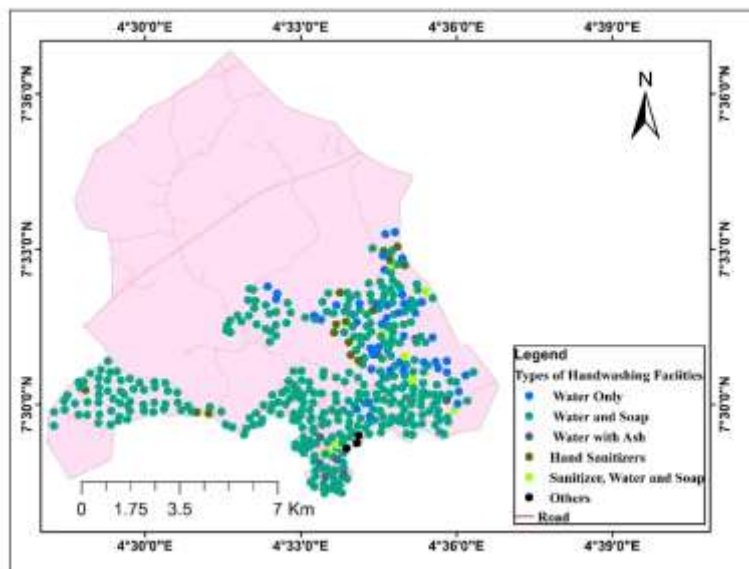


Figure 3: Spatial Distribution of Handwashing Facilities in Ife Central Local Government Area (sampled households). Source: Author's analysis

Distribution of WASH Facilities by Settlement Density

Variable	Category	Less-Dense (F)	Less-Dense (% , n=84)	Dense (F)	Dense (% , n=341)*	Total (F)	Total (% , N=425)*
Source of drinking water	Unprotected well	0	0.0%	7	2.1%	7	1.6%
	Protected well	17	20.2%	67	19.6%	84	19.8%
	Public tap/standpipe	0	0.0%	20	5.9%	20	4.7%
	Tube well/borehole	5	6.0%	20	5.9%	25	5.9%
	Sachet water	11	13.1%	45	13.2%	56	13.2%
	Bottled water	4	4.8%	13	3.8%	17	4.0%
	Piped water to neighbour	1	1.2%	2	0.6%	3	0.7%
	Piped water to yard/plot	8	9.5%	31	9.1%	39	9.2%
	Piped water into own dwelling	38	45.2%	136	39.9%	174	40.9%
Toilet facility	No facility / bush / field	3	3.6%	14	4.1%	17	4.0%
	Pit latrine without slab / open pit	1	1.2%	10	2.9%	11	2.6%

	Pit latrine with slab	0	0.0%	20	5.9%	20	4.7%
	Flush to pit latrine	0	0.0%	6	1.8%	6	1.4%
	Flush to open drain	5	6.0%	30	8.8%	35	8.2%
	Flush to septic tank	36	42.9%	93	27.3%	129	30.4%
	Flush to piped sewer system	39	46.4%	162	47.5%	201	47.3%
Handwashing facility	Water only	14	16.7%	30	8.8%	44	10.4%
	Water with ash	0	0.0%	8	2.3%	8	1.9%
	Hand sanitiser	7	8.3%	8	2.3%	15	3.5%
	Water and soap	63	75.0%	292	85.6%	355	83.5%
	Other	0	0.0%	3	0.9%	3	0.7%

Table 1: Distribution of household drinking-water sources, sanitation facilities, and handwashing facilities by settlement density, with within-group and overall percentages (N = 425).

Note: 6 respondents (all in the Dense settlement group) did not report a toilet facility and are shown as "Missing" above. All percentages are calculated out of the full valid sample (Dense n = 341; Total N = 425).

As shown in Table 1, the numerical distribution reinforces the mapped spatial observations, and the within-group percentages give a fairer basis for comparing settlement categories than the whole-sample percentages used in the original table. Piped water into the dwelling was the leading reported drinking-water source in both strata, while protected wells and sachet water were also important. For sanitation, flush-to-soakaway and flush-to-septic-tank systems accounted for the largest reported shares in both strata, though septic-tank facilities were relatively more common among less-dense households. For hygiene, water-and-soap facilities predominated in both strata, although water-only stations remained more common among less-dense households in relative terms even though more numerous in absolute terms among dense households.

Taken together with the exploratory chi-square results above, these findings suggest that settlement density is statistically associated with sanitation-facility type and handwashing-facility type among the households sampled, but not clearly with drinking-water source type. These associations describe the sampled households and should not be generalised to the full population of the LGA without further, more representative sampling or formal spatial-statistical confirmation.

DISCUSSION

The study demonstrates that WASH provision among the sampled households in Ife Central LGA is spatially heterogeneous rather than uniformly distributed across the study area. The mapped distribution of household WASH facilities indicates that households with different types and levels of access occur in distinct locations within the LGA. This finding is consistent with previous geospatial research demonstrating that spatial variations in WASH access may be obscured when findings are presented only as aggregate statistics. Ajisegiri et al. (2019), for example, demonstrated substantial geographical variation in access to water and sanitation across Nigeria through geospatial modelling. Similarly, Mobolaji and Akinwumiju (2025) showed that household WASH conditions in Nigeria vary geographically and are associated with demographic and socioeconomic characteristics. The present study extends this evidence by examining WASH conditions at a finer local scale within Ife Central LGA.

The concentration of unprotected wells around Akarabata is particularly important from a public-health perspective because unprotected water sources are more susceptible to contamination than protected sources. However, the observed concentration should be interpreted as a characteristic of the sampled households rather than as evidence that all households in Akarabata experience the same condition. Similarly, the higher absolute number of households without sanitation facilities and those using open or unlined pit latrines in the high-

density settlement area suggests that greater population concentration does not necessarily correspond to equitable WASH provision. This observation is consistent with the broader national evidence reported by WASHNORM, which documented substantial inequalities in access to WASH services across geographical areas, residence type, and socioeconomic groups (Federal Ministry of Water Resources, National Bureau of Statistics, World Bank, & UNICEF, 2022).

The findings also demonstrate the practical value of combining geospatial mapping with descriptive and comparative statistical analysis for WASH assessment. Georeferencing household facilities makes it possible to examine not only the proportion of sampled households with access to particular WASH facilities, but also their geographical distribution within the study area. This provides an additional dimension of information that can support local WASH planning and prioritisation. For example, areas in which inadequate water or sanitation facilities appear concentrated could be considered for further field investigation and, where confirmed by more comprehensive inventories, targeted interventions such as water-supply improvement, sanitation infrastructure development, or hygiene promotion.

The findings are further consistent with Nigerian geospatial research demonstrating the usefulness of spatial approaches for identifying geographical disparities in WASH provision (Ajisegiri et al., 2019; Mobolaji & Akinwumiju, 2025). At the local scale, the present study therefore provides additional evidence of the value of incorporating spatial information into WASH assessment, planning, monitoring, and evaluation. Nevertheless, the findings should be interpreted within the limitations of the study design and sampling framework. Because the analysis is based on sampled households, the observed spatial patterns should not be assumed to represent the entire population of Ife Central LGA without further investigation. Future studies could strengthen the analysis by incorporating socioeconomic characteristics, complete inventories of WASH facilities, water-quality measurements, and formal spatial-statistical techniques such as spatial autocorrelation, hotspot analysis, and cluster analysis. Such approaches would help determine whether the observed concentrations represent statistically significant spatial clusters of WASH deprivation.

LIMITATIONS

This study has several limitations.

- Cross-sectional design: findings represent a single point in time and cannot capture seasonal or longer-term change in WASH provision.
- Self-reported facility attributes: facility type, condition, and usage were not independently verified, and terms such as 'piped sewer' may have been interpreted inconsistently by respondents.
- Unequal settlement-strata sample sizes (84 vs. 341): comparisons are based on within-group percentages and exploratory chi-square tests, but several expected cell counts were small, and a design effect from the multistage sampling was not incorporated into the original sample-size calculation.
- No water-quality testing, collection-time, or reliability/availability data were collected, which limits the depth of comparison that can be made across facility types.
- Possible GPS positional error and classification error in facility attributes were not formally quantified.
- The spatial analysis reported here is primarily descriptive geospatial mapping and exploratory statistical comparison rather than formal spatial-statistical modelling (e.g., spatial autocorrelation, hotspot analysis, or spatial regression); apparent clustering on the maps may partly reflect the sampling design rather than the underlying phenomenon.
- The results describe the households sampled and are not a complete census of WASH infrastructure in Ife Central LGA; findings should not be extrapolated to the whole LGA without further representative sampling.

Ethics Statement

Ethical approval for this study was obtained from the Institute of Public Health, Obafemi Awolowo University prior to the commencement of data collection. Participation was voluntary, and informed consent was verbally obtained from an eligible adult household member (aged 18 years or above) before each interview. Households that declined to participate, or that withdrew consent at any point during the interview, were excluded from the study, as were households where informed consent could not be reliably obtained due to severe illness, incapacitation, cognitive impairment, intoxication, or an unresolved language barrier, and interviews that could not be conducted safely or privately due to environmental hazards, conflict, or security concerns.

Household GPS coordinates and questionnaire responses were assigned de-identified household codes and stored securely, with access restricted to the research team. Household coordinates were mapped at their original, unaltered precision and were not masked, jittered, or aggregated in the spatial analysis or in the figures presented in this study.

CONCLUSION

This study assessed the spatial distribution of household water, sanitation, and hygiene facilities in Ife Central Local Government Area using geospatial mapping and exploratory statistical comparison, based on a sample of 425 households. Among the households sampled, WASH facilities were unevenly distributed across the study area, and settlement density was statistically associated with sanitation-facility type and handwashing-facility type, but not with drinking-water source type. Piped water into dwellings was the leading reported drinking-water source, while protected wells and sachet water were also important. Sanitation facilities were dominated by flush-to-soakaway and flush-to-septic-tank systems in the sample, but locations without sanitation facilities and less adequate pit-latrines were also identified, particularly within dense settlements. Water-and-soap handwashing facilities represented the largest hygiene category, although water-only and other less complete facilities remained present, especially among dense-settlement households in absolute terms.

Geospatial mapping identified localised concentrations among sampled households, including unprotected wells around Akarabata and a broader pattern in which adequate WASH facilities appeared comparatively scarce and more evident, on visual inspection, in developed areas and near road networks — a pattern that warrants confirmation with formal proximity analysis. The study illustrates how geospatial mapping and exploratory statistical comparison can complement conventional household surveys by showing where, among sampled households, facility inequities appear to occur. With the methodological refinements identified in this review — particularly within-group comparisons, formal spatial-statistical testing, a reproducible density-classification protocol, and a complete ethics disclosure — the resulting evidence could support more targeted investment in piped-water infrastructure, improved sanitation, and hygiene promotion in neighbourhoods where mapped coverage is weakest, contributing to progress toward Sustainable Development Goal 6.

REFERENCES

1. Abdullahi, A., Abdullahi, M., & Bello, F. M. (2025). Statistical analysis of household access to Water, Sanitation and Hygiene (WASH) in North-Eastern Nigeria. *Journal of Systematic and Modern Science Research*.
2. Adejumo, T., Ogunlade, O., & Bello, A. (2021). Spatial inequalities in household access to water and sanitation in Nigeria. *African Population Studies*, 35(1), 112–130.
3. Adewole, A., & Ogunlade, T. (2019). GIS mapping of household water and sanitation access in South-West Nigeria. *Nigerian Journal of Geography and Environment*.
4. Ajisegiri, B., Andres, L. A., Bhatt, S., Dasgupta, B., Echenique, J. A., Gething, P. W., ... & Joseph, G. (2019). Geo-spatial modeling of access to water and sanitation in Nigeria. *Journal of Water, Sanitation and Hygiene for Development*, 9(2), 258-280.
5. Aliu, I. R., Akoteyon, I. S., & Soladoye, O. (2020). Living on the margins: Socio-spatial characterization of residential and water deprivations in Lagos informal settlements, Nigeria. *Habitat International*, 106, 102293. <https://doi.org/10.1016/j.habitatint.2020.102293>
6. Aliu, I. R., Akoteyon, I. S., Soladoye, O., & others. (2021). Household levels of deprivation to WaSH and residential conditions in slum settlements of Lagos, Nigeria. *Journal of Water, Sanitation and*



- Hygiene for Development*, 11(1), 60–74. <https://doi.org/10.2166/washdev.2020.157>
7. Ajisegiri, B., Andres, L. A., Bhatt, S., Dasgupta, B., Echenique, J. A., Gething, P. W., Zabludovsky, J. G., & Joseph, G. (2019). Geo-spatial modeling of access to water and sanitation in Nigeria. *Journal of Water, Sanitation and Hygiene for Development*, 9(2), 258–280. <https://doi.org/10.2166/washdev.2019.089>.
 8. Ayeni, A. O., Soneye, A. S. O., & Balogun, I. I. (2009). State of water supply sources and sanitation in Nigeria: Implications for Muslims in Ikare-Akoko Township. *The Arab World Geographer*, 12(1–2), 95–104.
 9. Ayeni, A. O., & Soneye, A. S. O. (2011). Mapping population water poverty of Akoko Northeast communities, Nigeria. In *Environmental research and challenges of sustainable development in Nigeria* (pp. 81–90). Obafemi Awolowo University Press.
 10. Awodumi, O., & Olatubara, C. O. (2023). Appraisal of household potable water accessibility in sub-urban areas of Oyo State: Geographic Information System and remote sensing approach. *Journal of Water Resources Engineering Management and Policy*, 10(1), 1–14.
 11. Bolarinwa, O. A. (2020). Sample size estimation for health and social science researchers: The principles and considerations for different study designs. *Nigerian Postgraduate Medical Journal*, 27(2), 67–75.
 12. Edefo, J. W. (2025). Water and sanitation access in Nigeria. *Water Conservation Science and Engineering*, 10(2), 72.
 13. Deaton, A. (2019). *The analysis of household surveys (reissue edition with a new preface): A microeconomic approach to development policy*. World Bank Publications.
 14. Fafunwa, T. S., Mogaji, H. O., Oluwole, A. S., Adeniran, A. A., Fagbenro, M. T., Sam-Wobo, S. O., Bada, B. S., & Ekpo, U. F. (2017). Water resource, hygienic practice, and soil transmitted helminthiasis in some rural communities of Osun State, Nigeria. *Journal of Water Resource and Protection*, 9(2), 109–119. <https://doi.org/10.4236/jwarp.2017.92008>.
 15. Federal Ministry of Water Resources, & National Bureau of Statistics. (2019). Water, Sanitation and Hygiene: National Outcome Routine Mapping (WASH-NORM) 2018: A report of findings. Federal Ministry of Water Resources.
 16. Federal Ministry of Water Resources, National Bureau of Statistics, & United Nations Children's Fund. (2022). *Water, sanitation and hygiene national outcome routine mapping 2021 (WASHNORM II): A report of findings*. Federal Ministry of Water Resources.
 17. Federal Ministry of Health and Social Welfare of Nigeria, National Population Commission, & ICF. (2024). *Nigeria Demographic and Health Survey 2023–24: Key indicators report*. National Population Commission and ICF.
 18. Kim, J., Hagen, E., Muindi, Z., Mbonglou, G., & Laituri, M. (2022). An examination of water, sanitation, and hygiene (WASH) accessibility and opportunity in urban informal settlements during the COVID-19 pandemic: Evidence from Nairobi, Kenya. *Science of the Total Environment*, 823, 153398. <https://doi.org/10.1016/j.scitotenv.2022.153398>
 19. Ntozini, R., Marks, S. J., Mangwadu, G., Mbuya, M. N. N., Gerema, G., Mutasa, B., Julian, T. R., Schwab, K. J., Humphrey, J. H., Zungu, L. I., & SHINE Trial Team. (2015). Using geographic information systems and spatial analysis methods to assess household water access and sanitation coverage in the SHINE trial. *Clinical Infectious Diseases*, 61(Suppl. 7), S716–S725. <https://doi.org/10.1093/cid/civ847>
 20. Mobolaji, J. W., & Akinwumiju, A. S. (2025). Geospatial assessment of household water, sanitation and hygiene conditions and associated factors in Nigeria: A causal relationship model. *PLOS ONE*, 20(8), e0330167. <https://doi.org/10.1371/journal.pone.0330167>
 21. National Population Commission. (2013). *Nigeria demographic and health survey 2013*. National Population Commission, ICF International.
 22. National Population Commission. (2022). Population projections for Local Government Areas in Nigeria based on 2006 census data. Abuja, Nigeria: NPC.
 23. Nwankwoala, H. O., & Okujagu, D. C. (2014). A review of wetlands and coastal resources of the Niger Delta: Potentials, Challenges and Prospects. *Environ. Ecosyst. Sci*, 5, 37–46.
 24. Okesanya, O. J., Eshun, G., Ukoaka, B. M., Manirambona, E., Olabode, O. N., Adesola, R. O., ... & Chowdhury, A. A. (2024). Water, sanitation, and hygiene (WASH) practices in Africa: exploring the effects on public health and sustainable development plans. *Tropical medicine and health*, 52(1), 68.



25. Oyegoke, O. A., Ogunwale, B. O., & Folorunso, I. A. (2025). Statistical Analysis of Open Defecation Practices and their Socioeconomic Determinants in Osun State, Nigeria. *Academic World Journal of Scientific and Engineering Innovation*, 2(1), 116-124.
26. Plan, S. S. A. (2018). United Nations 2023 Water Conference on the midterm comprehensive review of the implementation of the objectives of the International Decade for Action, "Water for Sustainable Development" 2018–2028. *Development*, 2018, 2028.
27. Pullan, R. L., Freeman, M. C., Gething, P. W., & Brooker, S. J. (2014). Geographical inequalities in use of improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. *PLoS medicine*, 11(4), e1001626.
28. Tetteh, J. D., Templeton, M. R., Cavanaugh, A., Owusu, G., Yidana, S. M., Moulds, S., Robinson, B., Baumgartner, J., Annim, S. K., Quartey, R., Mintah, S. E., Bawah, A. A., Arku, R. E., Ezzati, M., & Agyei-Mensah, S. (2022). Spatial heterogeneity in drinking water sources in the Greater Accra Metropolitan Area (GAMA), Ghana. *Population and Environment*, 44, 46–76.
<https://doi.org/10.1007/s11111-022-00407-y>
29. Kim, J., Hagen, E., Muindi, Z., Mbonglou, G., & Laituri, M. (2022). An examination of water, sanitation, and hygiene (WASH) accessibility and opportunity in urban informal settlements during the COVID-19 pandemic: Evidence from Nairobi, Kenya. *Science of the Total Environment*, 823, 153398.
<https://doi.org/10.1016/j.scitotenv.2022.153398>
30. World Health Organization. (2018). *Guidelines on sanitation and health*. World Health Organization.
<https://iris.who.int/handle/10665/274939>
31. World Health Organization. (2019). Progress on household drinking water, sanitation and hygiene 2000–2017. Geneva: WHO.
32. World Health Organization. (2020). WHO global water, sanitation and hygiene: annual report 2019.
33. World Health Organization. (2023). Progress on household drinking water, sanitation and hygiene 2000-2022: special focus on gender.
34. Yu, W., Bain, R. E. S., Mansour, S., & Wright, J. A. (2014). A cross-sectional ecological study of spatial scale and geographic inequality in access to drinking-water and sanitation. *International Journal for Equity in Health*, 13, 113. <https://doi.org/10.1186/s12939-014-0113-3>
35. Yu, W., Bain, R. E., Yu, J., Alegana, V., Dotse-Gborgbortsi, W., Lin, Y., & Wright, J. A. (2021). Mapping access to basic hygiene services in low-and middle-income countries: A cross-sectional case study of geospatial disparities. *Applied Geography*, 135, 102549.
36. Zhou, X. N., Xin-Yu, F., & Shang, X. (2018). Digital surveillance and communication strategies to infectious diseases of poverty control and elimination in Africa. *Journal of Infectious Diseases and Epidemiology*, 4(3).