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ASSESSMENT OF GROUNDWATER QUALITY IN AJAOKUTA LOCAL GOVERNMENT AREA, KOGI STATE, NIGERIA

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ABSTRACT

Groundwater serves as the primary water source for domestic, agricultural, and industrial activities in Ajaokuta Local Government Area (LGA), where rapid industrial expansion poses increasing risks of aquifer contamination. This study assessed the physicochemical quality of groundwater in Ajaokuta LGA, using five well-water samples collected across the region. The samples were analyzed for pH, salinity, electrical conductivity, total dissolved solids (TDS), total hardness, alkalinity, and key metal concentrations (Ca, Mg, Mn, Fe, Cu, Pb, Zn). Descriptive statistics and one-way Analysis of Variance (ANOVA) were used to evaluate spatial variation and compliance with World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines. Results indicate significant spatial variability, with ANOVA p-values < 0.001 across most parameters. Iron levels reached 1.85 mg/L (WHO limit: 0.3 mg/L) and lead levels peaked at 0.017 mg/L (WHO limit: 0.01 mg/L). Electrical conductivity, TDS, and total hardness also exceeded permissible limits in some locations. The findings reveal critical contamination hotspots linked to industrial and mining activities within the LGA. The study recommends enhancing regulatory enforcement, providing alternative potable water sources, implementing groundwater monitoring programs, and conducting community-based awareness campaigns.

INTRODUCTION

Groundwater constitutes a major source of drinking water and agricultural supply, supporting millions of people globally. Its quality is influenced by both natural processes and anthropogenic activities (UNEP, 2018; Ibrahim et al., 2017). Industrialization particularly manufacturing, mining, chemical processing, and steel production, commonly introduces pollutants such as heavy metals and organic chemicals into aquifers (Akinola, Ayeni & Ogundipe, 2022). These contaminants pose significant human health risks, including neurological, carcinogenic, and gastrointestinal diseases (Ibrahim et al., 2017).

Ajaokuta Local Government Area in Kogi State has expanded industrially with the establishment of large-scale operations, especially the Ajaokuta Steel Complex. While these industries enhance economic opportunities, they have increased the risk of groundwater contamination through effluent discharge, mining waste, and leaching (Ojo et al., 2018). Given that groundwater remains the major water supply for residents, evaluating its quality is critical for environmental sustainability and public health.

This paper assesses the physicochemical characteristics of groundwater in Ajaokuta, compares results with national and international standards, and evaluates possible implications for human health and the environment.

Statement of the Problem

Residents of Ajaokuta LGA rely heavily on groundwater due to limited access to treated surface water. However, industrial and mining activities including the Ajaokuta Steel Complex, pose significant contamination risks. Previous studies reported elevated levels of Fe, Mn, Cr, and As in groundwater, often exceeding WHO limits (Ogunyemi et al., 2023; Ilesanmi et al., 2023). For instance, Fe concentrations of 0.45 mg/L and Mn concentrations of 0.06 mg/L were recorded near industrial zones, surpassing WHO guidelines (Orosun et al., 2016). Bacteriological contaminants such as *E. coli* have also been detected (Bamidele et al, 2023).

Despite these concerns, updated and comprehensive assessments covering both physical and chemical parameters remain limited. This creates a knowledge gap for effective regulation and public safety. This study therefore provides an updated, systematic analysis of groundwater quality in Ajaokuta.

Objectives of the Study

The study aims to assess groundwater quality in Ajaokuta LGA. Specifically, it seeks to:

1. Determine the physicochemical properties of groundwater in selected locations.
2. Compare findings with WHO and NSDWQ standards.
3. Examine potential health and environmental risks associated with contaminated

groundwater.

Area of Study

Ajaokuta LGA covers about 1,300 km² and lies between latitude 7.5000° N and longitude 6.7000° E. The climate is tropical with an annual rainfall of 1,200–1,500 mm and temperatures ranging between 25°C and 35°C. The vegetation varies from rainforest to savanna, with soils dominated by ferrallitic types. The region is geologically underlain by Precambrian Basement Complex rocks rich in iron ore deposits, which support the steel industry. Socioeconomic activities include agriculture, mining, steel production, and trade.

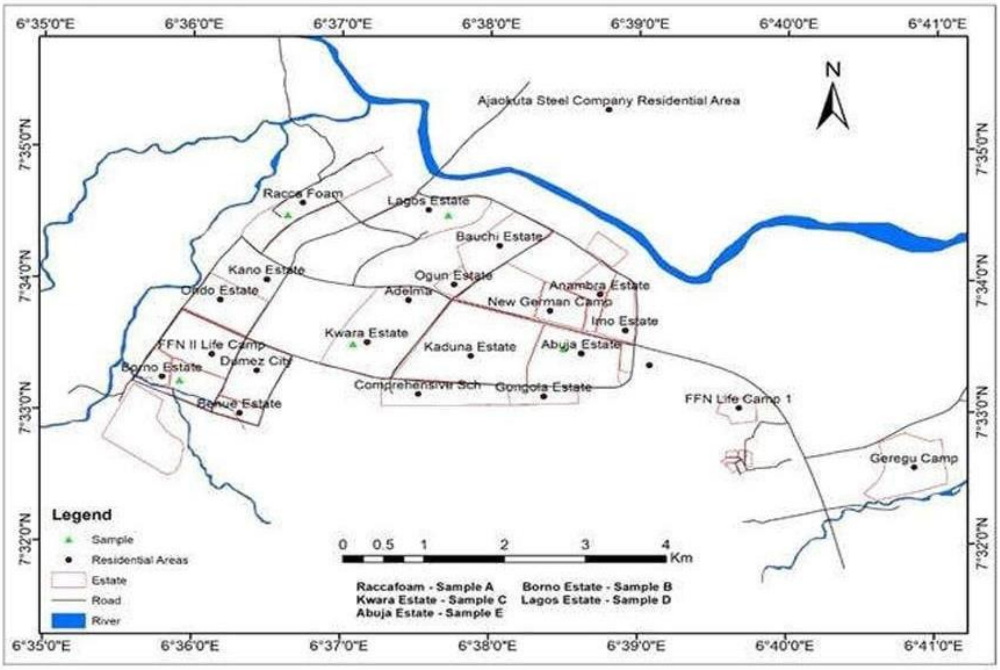

Fig 1: Map of Ajaokuta Local Government Area Showing Well Water Sample Location.

Source: Author's Analysis, (2025)

Methodology

This study adopted a field-based research design to assess the physicochemical properties of groundwater across selected locations in Ajaokuta LGA. Primary data were obtained through the collection of groundwater samples, followed by laboratory analysis and statistical evaluation. Data required included physical parameters (pH, salinity, electrical conductivity, total dissolved solids, total hardness) and chemical parameters (total alkalinity, calcium, magnesium, manganese, copper, iron, lead, zinc). Data were sourced from field sampling and laboratory tests.

A purposive sampling method was used to select five locations based on proximity to industrial sites and residential reliance on groundwater. Five groundwater samples were collected from hand-dug wells. Water samples were collected using pre-cleaned plastic containers, sealed, labeled, and transported to the laboratory for analysis. Standard procedures were followed to avoid contamination. Laboratory analysis followed WHO and NSDWQ guidelines. Parameters measured included pH (electrometric method), salinity, electrical conductivity, TDS, total hardness, alkalinity, and concentrations of Ca, Mg, Mn, Cu, Fe, Pb, and Zn. Descriptive statistics and Analysis of Variance (ANOVA) were used to determine spatial variations. Values were compared with WHO (2017, 2021) and NSDWQ (FME, 2019) standards.

RESULTS

Physical Properties

- **pH:** ranged within slightly acidic to slightly alkaline conditions; some samples approached lower WHO limits (6.5–8.5).

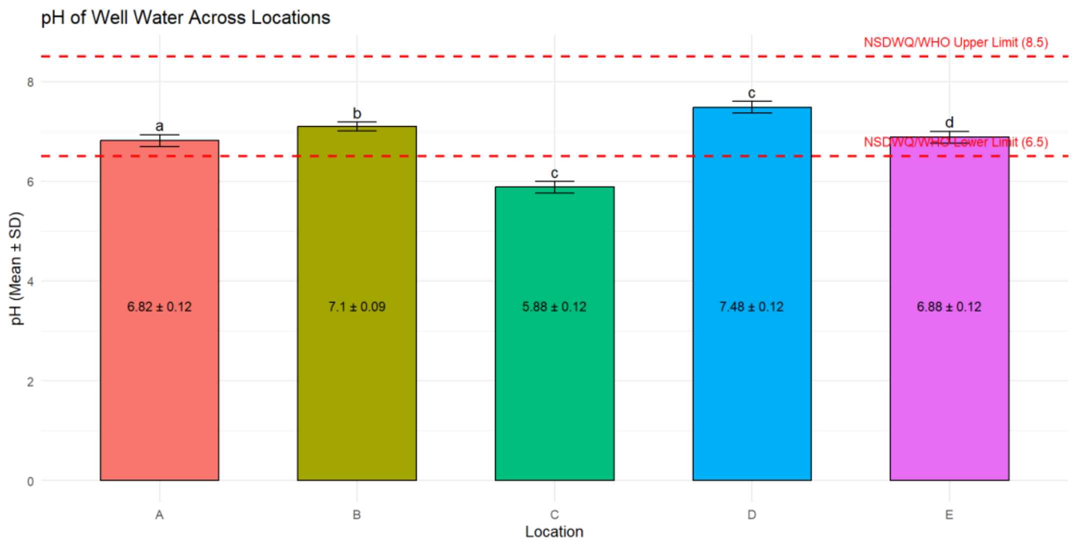

Figure 2: pH Concentration in the Study Area.

Source: Author's Analysis, 2025

- **Electrical Conductivity:** EC values displayed significant variation ($p < 0.001$). Some locations exceeded WHO's recommended value of 250 µS/cm, suggesting high ionic concentration likely originating from industrial waste infiltration.

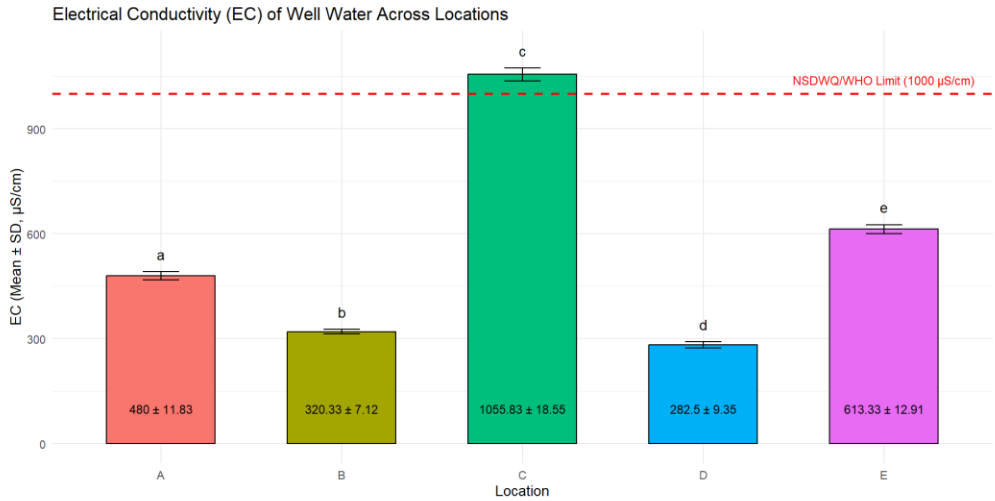

Figure 3: Electrical Conductivity Concentration in the Study Area.

Source: Author's Analysis, 2025

- **TDS:** elevated values in some locations reflect high mineralization, surpassing NSDWQ thresholds.

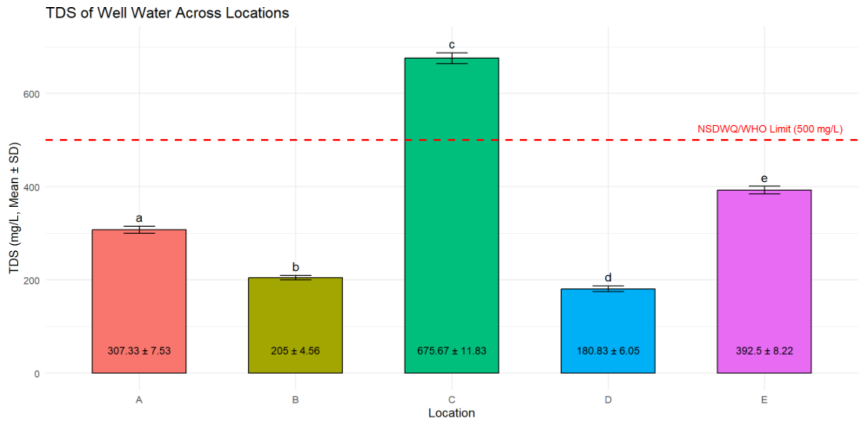

Figure 4: Total Dissolved Solids of Well Water in the Study Area.

Source: Author's Analysis, 2025

- **Total Hardness:** Hardness values exceeded the WHO limit (100 mg/L) in several locations, indicating high Ca and Mg levels typical of basement complex regions but also influenced by industrial waste seepage.

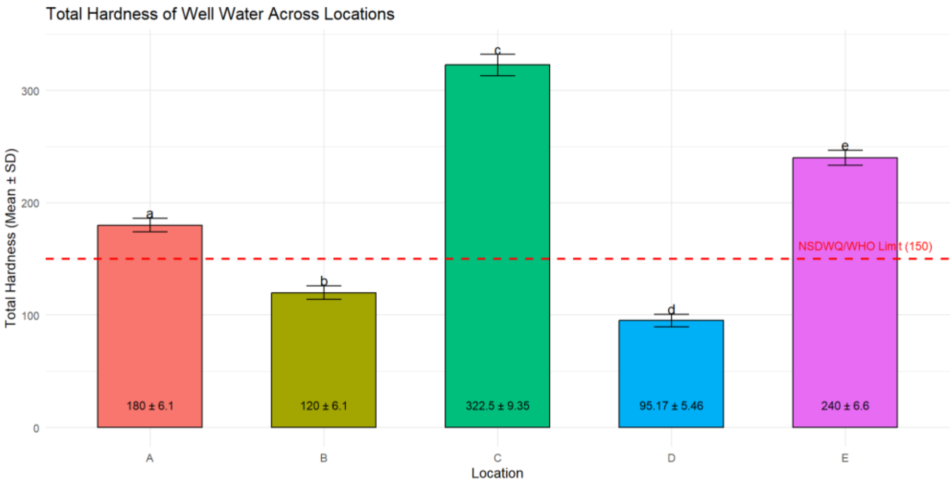

Figure 5: Total Hardness of Well Water in the Study Area.

Source: Author’s Analysis, 2025

Chemical Properties

- **Lead (Pb):** recorded up to 0.017 mg/L (WHO limit = 0.01 mg/L).

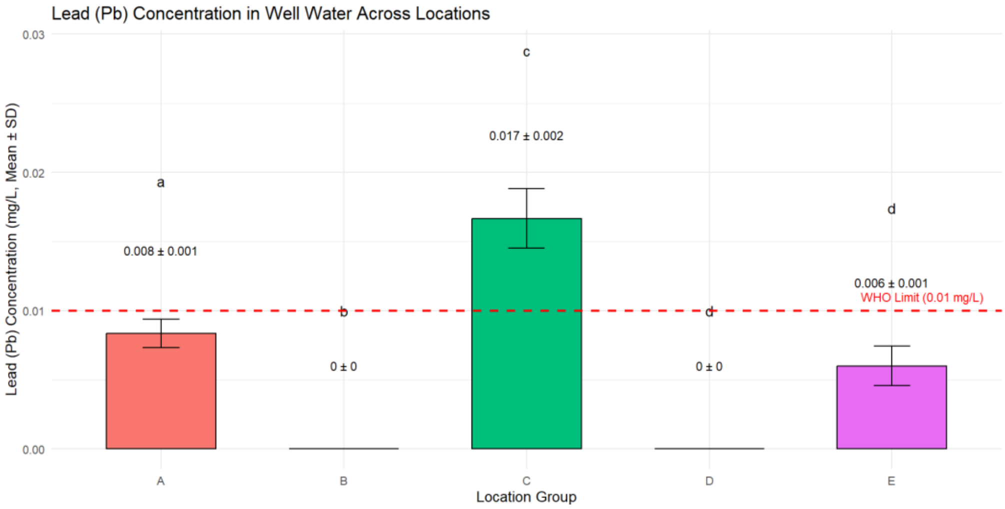

Figure 6: Lead Concentration of Well Water in the Study Area.

Source: Author’s Analysis, 2025

- **Iron (Fe):** reached 1.85 mg/L (WHO limit = 0.3 mg/L).

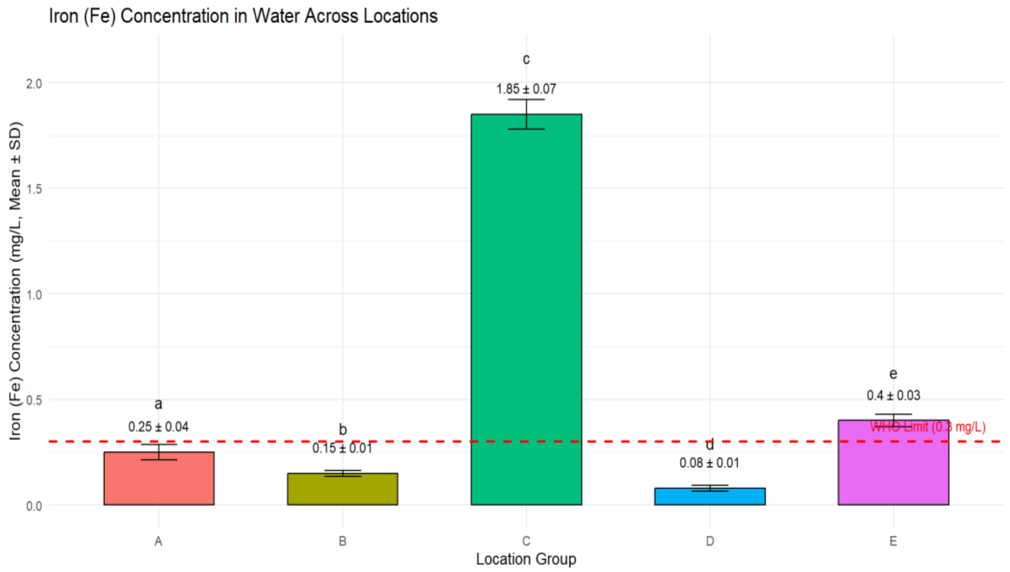

Figure7: Iron Concentration of Well Water in the Study Area.

Source: Author's Analysis, 2025

- **Manganese (Mn):** exceeded WHO limits in some sampling sites.

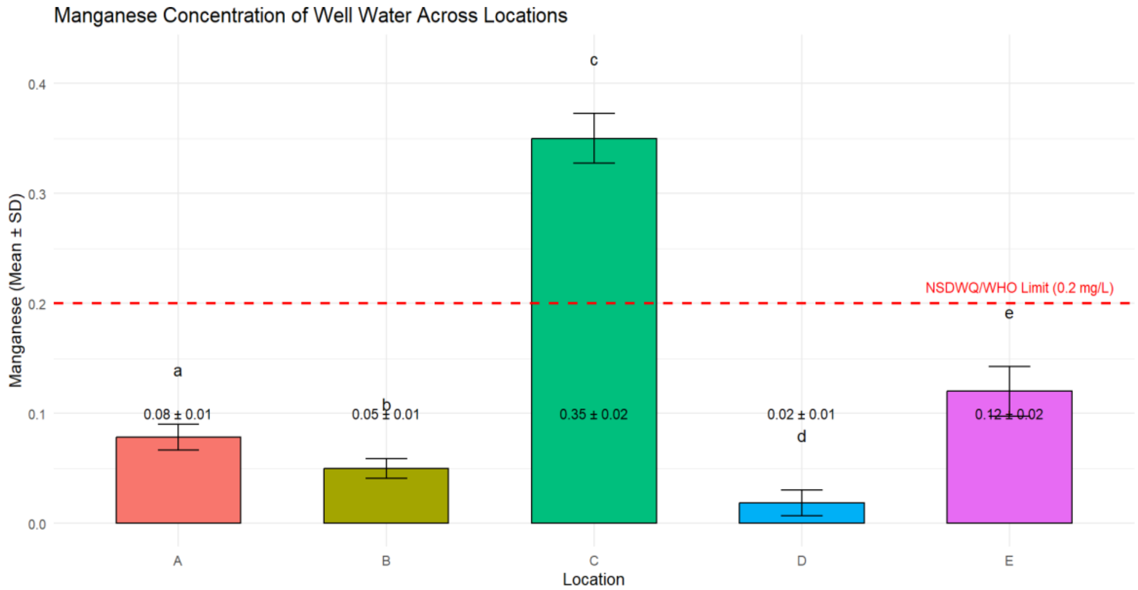

Figure 8: Manganese Concentration of Well Water in the Study Area.

Source: Author's Analysis, 2025

- **Magnesium and Calcium:** varied significantly across locations, with some values above permissible limits.

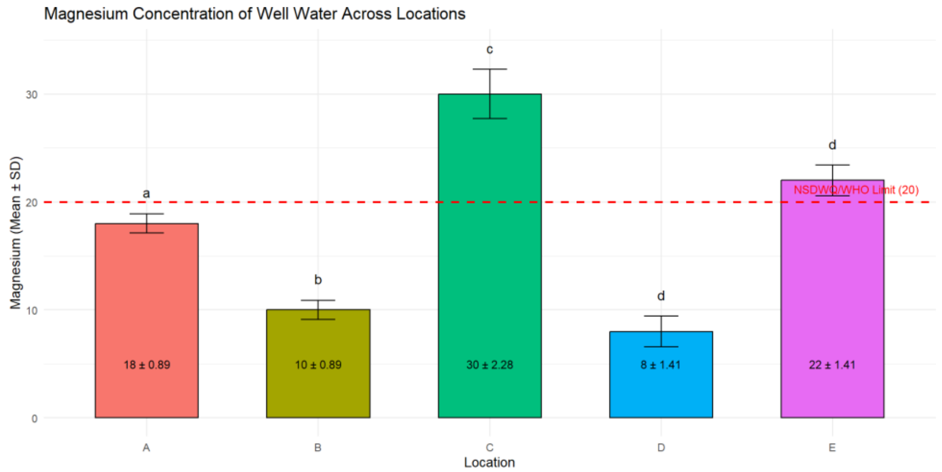

Figure 9: Magnesium Concentration of Well Water in the Study Area.

Source: Author's Analysis, 2025

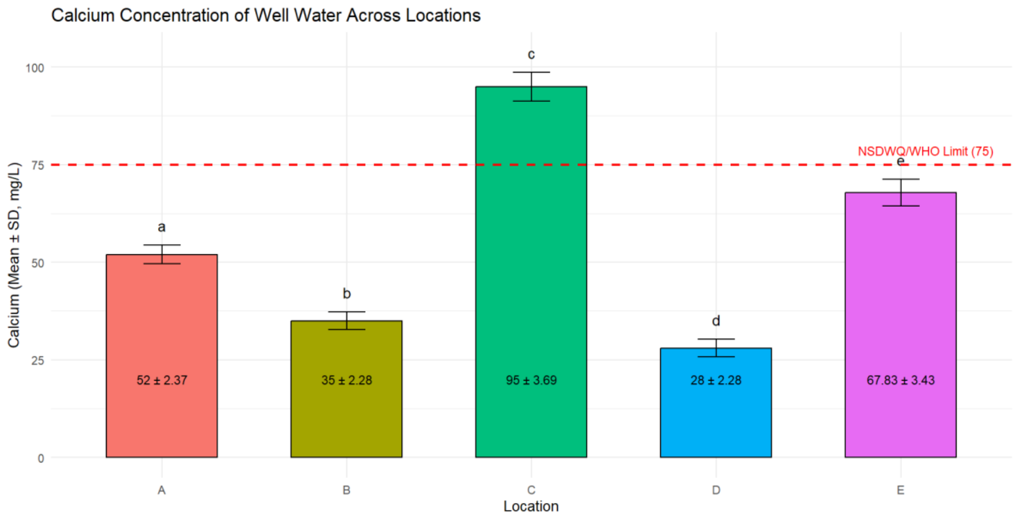

Figure 10: Calcium Concentration of Well Water in the Study Area

Source: Author's Analysis, 2025

- **Copper and Zinc:** mostly within acceptable limits but showed spatial variability.

Figure 11: Copper Concentration of Well Water in the Study Area

Source: Author's Analysis, 2025

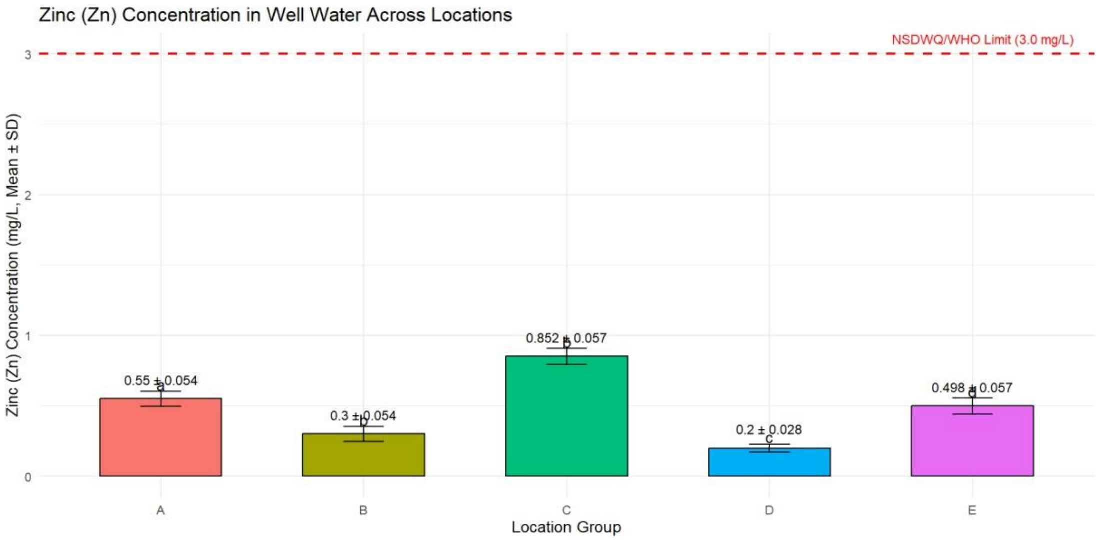

Figure 12: Zinc Concentration of Well Water in the Study Area.

Source: Author's Analysis, 2025

Statistical Significance

Table 1: ANOVA Analysis of Physical Properties of well water in the study area.

Property	Group Mean Sq	Residual Mean Sq	F value	p-value
pH	2.0983	0.0125	167.4202	0.0000
Salinity	0.0386	0.0003	126.9079	0.0000
Electrical Conductivity	583,621.05	157.8	3,698.49	0.0000
Total Dissolved Solids	238,953.22	64.28	3,717.38	0.0000
Total Hardness	51,056.78	47.0533	1,085.08	0.0000

Source: Author's Analysis (2025)

Table 4.1 shows that all five physical water quality parameters—pH, salinity, electrical conductivity (EC), total dissolved solids (TDS), and total hardness—exhibit highly significant variation across the sampled locations in Ajaokuta LGA. The extremely high F-values (ranging from 126.91 to 3,717.38) and p-values of 0.0000 confirm that differences in physical water properties are not due to random chance. Instead, the variations are driven by geological differences, industrial activities, mining operations, and heterogeneous aquifer conditions.

The strongest variations occurred in EC (F = 3,698.49) and TDS (F = 3,717.38), indicating substantial ionic enrichment likely linked to metallurgical and mining operations. These results align with findings from Nigeria, Ghana, Greece, and India, where similar ANOVA outcomes were attributed to effluent discharge, mining runoff, and mineral dissolution. The significant variation in total hardness (F = 1,085.08) reflects the influence of carbonate-rich formations that increase calcium and magnesium concentrations in groundwater.

Table 2: ANOVA Analysis of Chemical Properties of well water in the study area

Property	Group Mean Sq	Residual Mean Sq	F value	p-value
Total Alkalinity	3,517.80	15.84	222.0833	0.0000
Calcium	4,351.63	8.2733	525.9831	0.0000
Magnesium	484.8	2.16	224.4444	0.0000
Manganese	0.1047	0.0003	375.8074	0.0000
Copper	0.0369	0.0005	69.9778	0.0000
Iron (Fe)	3.275	0.0015	2,165.99	0.0000
Lead (Pb)	0.0003	0	185.2586	0.0000
Zinc (Zn)	0.3813	0.0026	144.0523	0.0000

Source: Author’s Analysis, (2025)

Table 4.2 indicates that all chemical parameters analyzed; total alkalinity, calcium, magnesium, manganese, copper, iron (Fe), lead (Pb), and zinc (Zn), show statistically significant differences across sampling locations, with all p-values = 0.0000 and F-values ranging from 69.98 to 2,165.99. This confirms that chemical contamination is not uniform but varies widely due to environmental, geological, and industrial influences.

The most pronounced variations were seen in iron (F = 2,165.99) and manganese (F = 375.81), reflecting strong geochemical disturbance commonly associated with mining activities, oxidation of sulfide minerals, and industrial discharge. Significant variation in calcium and magnesium also points to differences in lithology, such as the presence of dolomitic or calcareous formations.

The variation in toxic metals especially lead (F = 185.26) and copper (F = 69.98) raises public health concerns, as certain locations may exceed safe limits. The highlighted patterns are consistent with previous studies in Ghana, Greece, and Nigeria showing that mining regions often experience elevated metal concentrations and strong spatial variability.

DISCUSSION

Industrial effluents, mine drainage, and leaching from waste dumps appear to contribute significantly to groundwater contamination. Elevated heavy metals such as Fe and Pb indicate possible seepage from steel processing and mining operations. High EC, TDS, and hardness suggest mineral dissolution and anthropogenic inputs. These contaminants pose severe health risks, including neurological damage, kidney disorders, and carcinogenic effects.

Environmental impacts may include reduced soil fertility, ecosystem disruption, and bioaccumulation of heavy metals in plants and aquatic organisms. The strong spatial variability further reflects uneven distribution of industrial activities and hydrogeological conditions.

CONCLUSION

Groundwater in Ajaokuta Local Government Area shows significant physicochemical contamination, with several parameters exceeding WHO and NSDWQ safety limits. Industrial and mining activities are the most probable contributors. There is a clear public health risk for communities dependent on untreated groundwater.

RECOMMENDATIONS

The study recommends the followings.

1. Immediate provision of alternative safe water sources such as treated boreholes and household purification systems.
2. Strict enforcement of environmental regulations by NESREA and KSEPA.
3. Continuous monitoring of groundwater quality across industrial zones.
4. Installation of effluent treatment systems in industries.
5. Public awareness campaigns on risks associated with contaminated groundwater.
6. Hydrogeological mapping and pollution source tracking to guide remediation.

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