

Assessment of the Selected Physicochemical Properties of Well Water in Isuofia Aguata Local Government Area, Anambra State, Nigeria.

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ABSTRACT

Background: Access to safe drinking water remains a critical challenge in rural Nigeria, where contaminated well water contributes to waterborne diseases. This study assessed the physicochemical properties and heavy metal concentrations of well water in Isuofia, Aguata Local Government Area, Anambra State, to evaluate its suitability for human consumption and inform water management strategies.

Materials and Methods: A cross-sectional study sampled 12 wells randomly across six villages during the dry season. Parameters including pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), and heavy metals (chromium, copper, mercury, iron, lead) were analyzed using calibrated multi-parameter instruments and atomic absorption spectrophotometry. Data were compared to WHO and NSDWQ standards using Pearson's correlation. **Results:** Findings revealed alkaline pH (8.0–10.6, mean 9.42 ± 0.76 ; 75% exceeding 6.5–8.5), high TDS (0.47–7.78 g/L, mean 2.16 ± 1.92 g/L; 83.3% exceeding 1.0 g/L), elevated temperatures (32.0–38.5°C, mean 34.92 ± 1.94 °C), and EC (0.005–0.118 $\mu\text{S}/\text{cm}$, below 1000 $\mu\text{S}/\text{cm}$). Lead (83.3%), mercury (75%), and copper (58.3%) exceeded WHO limits, while chromium and iron were within safe levels.

Discussion and Implications: Exceedances, likely from agricultural runoff, waste disposal, and geological factors, pose risks of neurological and gastrointestinal issues, particularly for children.

Conclusion: These findings confirm hypotheses on TDS, EC, and heavy metal exceedances, underscoring the urgent need for regular monitoring, point-of-use filtration, public awareness, and infrastructure upgrades to ensure safe drinking water and support sustainable water management in rural Nigeria.

Keywords: Well water quality, Physicochemical properties, Heavy metals, Groundwater contamination, pH, Total dissolved solids, Electrical conductivity, Lead contamination, Mercury contamination, Water management.

INTRODUCTION

Water is an essential resource critical for life, ecosystems, and socio-economic activities, owing to its unique properties as a universal solvent and its role in the hydrological cycle (UNESCO, 2018). The continuous movement of water through evaporation, condensation, precipitation, and infiltration replenishes freshwater resources, yet global demand driven by population growth, urbanization, and industrialization threatens water quality and availability (UN Water, 2022). In developing countries like Nigeria, access to safe drinking water remains a significant challenge, with 63 million people lacking access, contributing to 100,000 annual deaths from waterborne diseases and economic losses of approximately ₦455 billion (WHO/UNICEF, 2020; World Bank, 2019). Contaminated water sources, particularly in rural areas, exacerbate health risks, including diarrhea, cholera, and dysentery, with children under five being the most vulnerable (UNESCO, 2021). In Isuofia, Aguata Local Government Area (LGA), Anambra State, well water sourced from rainwater infiltration serves as a primary drinking water source. However, limited data on its physicochemical properties raise concerns about its safety, given potential contamination from environmental, geological, and anthropogenic factors (Adejuwon & Afuwape, 2018). The physicochemical properties of water, including pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), and heavy metal concentrations, are key indicators of its suitability for human consumption (Xaaceph & Butt, 2022). These parameters influence water's chemical behavior, ecological impact, and health risks. For instance, pH affects metal solubility, with acidic conditions ($\text{pH} < 7$) increasing the bioavailability of toxic metals like lead, while high TDS and EC indicate potential contamination from dissolved salts or pollutants (Meride & Ayenew, 2016). Heavy metals, such as iron and lead, pose risks of bioaccumulation, leading to chronic conditions like cancer and neurological disorders (Jamshaid et al., 2018).

Geologically, Isuofia lies within the Nanka Sand Formation of the Bende-Ameki Group, characterized by sandstone, shale, and limestone, which influence groundwater quality through mineral dissolution (Onyenweife & Imezi, 2024). The region's tropical forest vegetation and high rainfall facilitate aquifer recharge, but agricultural runoff and improper waste disposal may introduce contaminants, lowering pH and increasing heavy metal levels. Previous studies in Aguata LGA report pH levels of 5.4–6.4, indicating acidic water, and heavy metal concentrations (e.g., iron, manganese) within WHO limits, though lead occasionally exceeds safe thresholds (Onyenweife & Imezi, 2024). These findings highlight the need for localized assessments in Isuofia to ensure water safety. Poor water quality has significant health and economic impacts. Waterborne diseases contribute to 80% of illnesses in Nigeria, straining healthcare systems and reducing productivity (FMoH, 2018). Malnutrition, exacerbated by gastrointestinal illnesses from contaminated water, affects child development, while economic losses hinder community development (Luvhimbi et al., 2022). This study aims to assess the physicochemical properties of well water in Isuofia, focusing on pH, temperature, TDS, EC, and heavy metals, to identify contaminants and inform water management strategies. By addressing these issues, the study will contribute to public health protection, sustainable water management, and policy development in rural Nigeria, aligning with global efforts to ensure access to safe drinking water (WHO, 2021).

MATERIALS AND METHODS

A quantitative cross-sectional study assessed selected physicochemical properties of well water in Isuofia, Nigeria, during the dry season. Twelve wells (24% of 50) were randomly selected across six villages which covers almost 50% of the wells in the study area. Simple random sampling technique was applied to select the wells, hence names were assigned to the wells as well 1-well 50 and random selection was performed using computer random selection system. The essence is to make sure that no selection bias is introduced in the study, For the selected well, water samples were collected using 1.5 litre sterilized containers, with parameters including pH, temperature, electrical conductivity, total dissolved solids (TDS) were measured in-situ using a multi-parameter instrument. Three readings were taken, and the mean value recorded. and heavy metals (lead, cadmium, arsenic) analyzed with atomic absorption spectrophotometry in public health Laboratory. Instruments were validated through calibration against standard protocols to ensure accuracy. Data analysis employed Pearson's correlation to compare results with WHO

drinking water guidelines, identifying deviations and contamination risks. Ethical approval was obtained from Nnamdi Azikiwe University ethical committee, with informed community consent and anonymized data handling. This systematic approach aimed to evaluate health risks and inform targeted interventions for safe water access.

RESULTS

Table 1.1 shows summary of the mean physicochemical parameters of the 12 well water samples (labeled A to L), including pH, TDS, temperature, and EC, compared against WHO and NSDWQ standards. pH: The pH values ranged from 8.0 to 10.6, with a mean of 9.42 ± 0.76 . Nine of the 12 samples (75%) exceeded the WHO and NSDWQ acceptable range of 6.5–8.5, indicating alkaline conditions.

Total Dissolved Solids (TDS): TDS levels ranged from 0.47 to 7.78 g/L, with a mean of 2.16 ± 1.92 g/L. Ten of the 12 samples (83.3%) exceeded the WHO and NSDWQ limit of 1.0 g/L, supporting the hypothesis that TDS levels may exceed safe limits. High TDS levels indicate elevated concentrations of dissolved salts and minerals,

Temperature: The temperature ranged from 32.0 to 38.5°C, with a mean of 34.92 ± 1.94 °C. All 12 samples exceeded typical ambient groundwater temperatures (typically <30°C), supporting the hypothesis that temperature influences water chemistry.

Electrical Conductivity (EC): EC values ranged from 0.005 to 0.118 $\mu\text{S}/\text{cm}$, with a mean of 0.031 ± 0.030 $\mu\text{S}/\text{cm}$. Notably, none of the samples exceeded the WHO and NSDWQ limit of 1000 $\mu\text{S}/\text{cm}$, suggesting that ion concentrations, while present, are within safe limits for conductivity. However, the hypothesis that EC correlates with ion concentration is supported, as EC reflects the presence of dissolved ions.

Table 1.2 shows the concentrations of five heavy metals (chromium, copper, mercury, iron, and lead) in the well water samples, with contamination factors (CF) and comparisons to WHO permissible limits.

Chromium: Concentrations ranged from 0.00088 to 0.0153 mg/L, with a mean of 0.00678 ± 0.00533 mg/L. All samples were below the WHO limit of 0.05 mg/L (CF < 1), indicating no exceedance.

Copper: Concentrations ranged from 0.1376 to 0.2860 mg/L, with a mean of 0.20149 ± 0.04973 mg/L. Seven of the 12 samples (58.3%) exceeded the WHO limit of 0.2 mg/L, with CF values ranging from 0.688 to 1.430.

Mercury: Concentrations ranged from 0.0040 to 0.0554 mg/L, with a mean of 0.01961 ± 0.01721 mg/L. Nine of the 12 samples (75%) exceeded the WHO limit of 0.006 mg/L, with CF values up to 9.233.

Iron: Concentrations ranged from 0.0597 to 0.1462 mg/L, with a mean of 0.10417 ± 0.02676 mg/L. All samples were below the WHO limit of 0.3 mg/L, indicating no exceedance.

Lead: Concentrations ranged from 0.0026 to 0.0622 mg/L, with a mean of 0.02284 ± 0.01711 mg/L. Ten of the 12 samples (83.3%) exceeded the WHO limit of 0.01 mg/L, with CF values up to 6.220.

Table 1.1 Summary of the Selected Physicochemical Parameters of the 12 well Water Samples, including pH, TDS, temperature, and EC, compared against WHO and NSDWQ standards

Physicochemical Properties of Well Water Samples from Isuofia Compared with WHO and NSDWQ Standards									
	Samples	pH(acidic-alkaline) 0-14	Exceed (pH)	TDS (g/L)	Exceed (TDS)	Temp (°C)	Exceed (Temp)	EC (µS/cm)	Exceed (EC)
Well Water Samples	A	9.2	Yes	1.63	Yes	38.5	Yes	0.027	No
	B	9.6	Yes	1.62	Yes	33.5	Yes	0.030	No
	C	9.7	Yes	1.61	Yes	34.8	Yes	0.029	No
	D	9.0	Yes	2.10	Yes	37.8	Yes	0.017	No
	E	8.4	No	2.94	Yes	36.0	Yes	0.023	No
	F	9.7	Yes	2.78	Yes	34.0	Yes	0.022	No
	G	9.7	Yes	1.11	Yes	33.5	Yes	0.024	No
	H	10.6	Yes	1.58	Yes	32.0	Yes	0.118	No
	I	8.0	No	1.72	Yes	33.5	Yes	0.007	No
	J	8.2	No	0.60	Yes	34.0	Yes	0.005	No
	K	9.7	Yes	0.47	No	33.2	Yes	0.039	No
	L	10.4	Yes	7.78	No	33.8	Yes	0.027	No
	Mean	9.42	-	2.16	-	34.92	-	0.031	-
	SD	0.76	-	1.92	-	1.94	-	0.030	-
	Summary	9/12 exceed	-	10/12 exceed	-	12/12 exceed	-	0/12 exceed	-
	NSDWQ Limit	6.5-8.5	-	1.0	-	-	-	1000	-
	WHO Limit	6.5-8.5	-	1.0-	-	-	-	1000	-

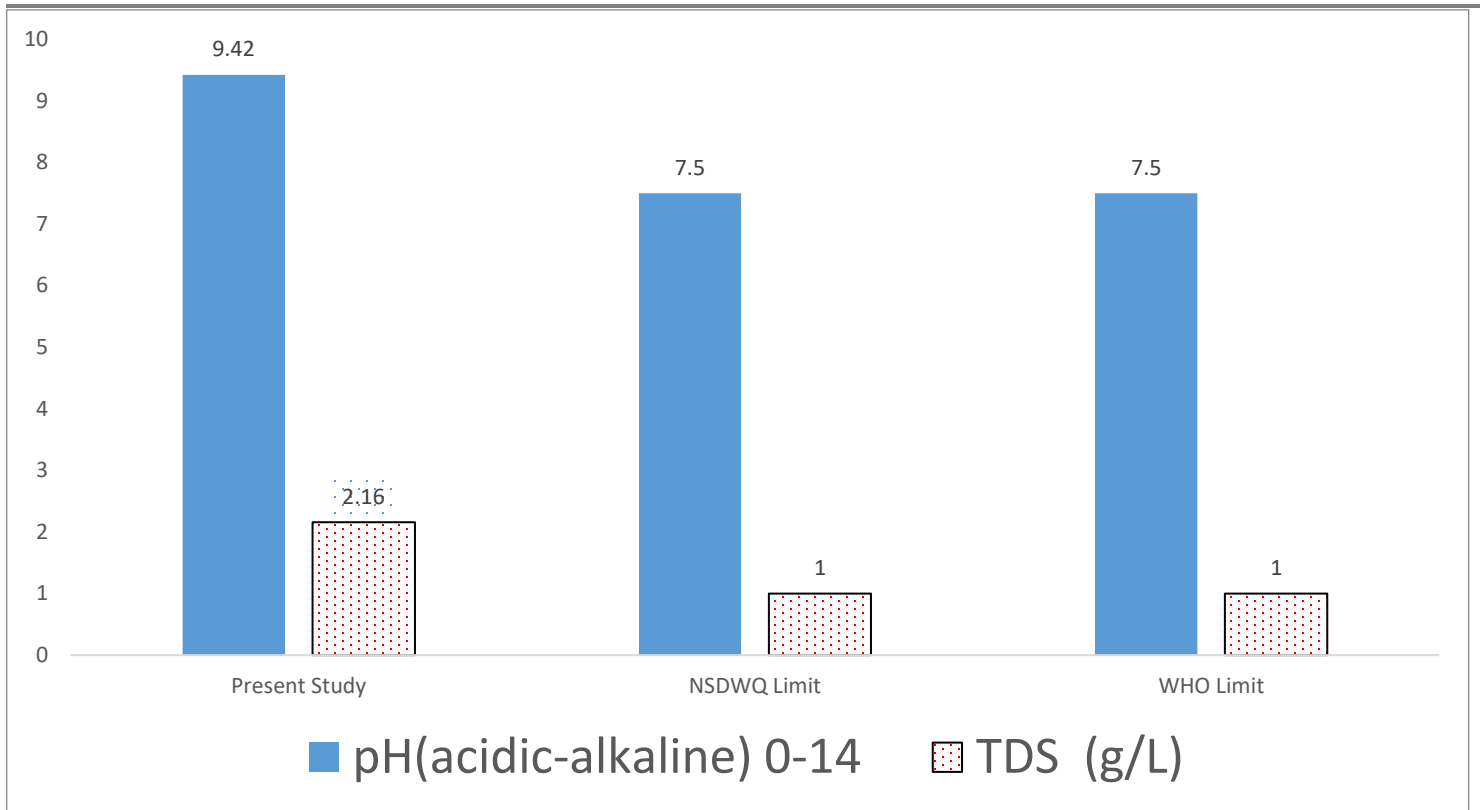


Figure 1: Mean study pH and TDS compared with NSDWQ limit and WHO Limit

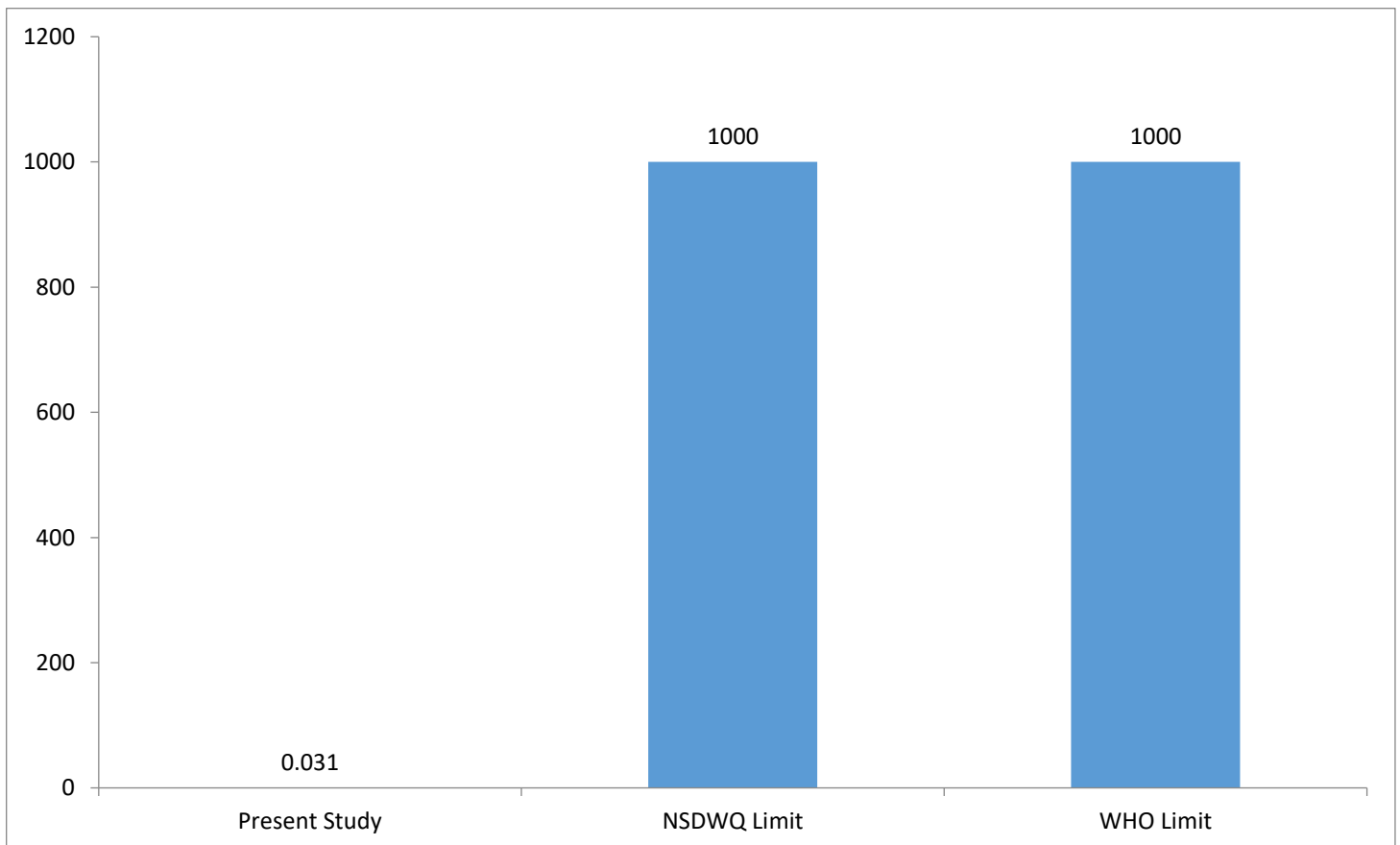


Figure 2: Mean study EC ($\mu\text{S/cm}$) compared with NSDWQ limit and WHO Limit

Table 1.2 Concentrations of five heavy metals (chromium, copper, mercury, iron, and lead) in the well water samples, with contamination factors (CF) and comparisons to WHO permissible limits.

Samples	Chromium Conc. (mg/L)	CF (Cr)	Exceed CF	Copper Conc. (mg/L)	CF (Cu)	Exceed (Cu)	Mercury Conc. (mg/L)	CF (Hg)	Exceed (Hg)	Iron Conc. (mg/L)	CF (Fe)	Exceed (Fe)	Lead Conc. (mg/L)	CF (Pb)	Exceed (Pb)
A	0.0067	0.134	No	0.2012	1.006	Yes	0.0231	3.850	Yes	0.1258	0.419	No	0.0233	2.330	Yes
B	0.0023	0.046	No	0.1376	0.688	No	0.0262	4.367	Yes	0.1239	0.413	No	0.0156	1.560	Yes
C	0.0128	0.256	No	0.2265	1.133	Yes	0.0185	3.083	Yes	0.1084	0.361	No	0.0441	4.410	Yes
D	0.0110	0.220	No	0.2139	1.070	Yes	0.0145	2.417	Yes	0.0937	0.312	No	0.0285	2.850	Yes
E	0.0088	0.176	No	0.2647	1.324	Yes	0.0115	1.917	Yes	0.0854	0.285	No	0.0207	2.070	Yes
F	0.0055	0.110	No	0.1547	0.774	No	0.0135	2.250	Yes	0.0688	0.229	No	0.0026	0.260	No
G	0.00099	0.020	No	0.1737	0.869	No	0.0099	1.650	Yes	0.0597	0.199	No	0.0207	2.070	Yes
H	0.0153	0.306	No	0.2520	1.260	Yes	0.0554	9.233	Yes	0.1462	0.487	No	0.0622	6.220	Yes
I	0.0138	0.276	No	0.2860	1.430	Yes	0.0040	0.667	No	0.1324	0.441	No	0.01295	1.295	Yes
J	0.0011	0.022	No	0.1419	0.710	No	0.0043	0.717	No	0.0926	0.309	No	0.01036	1.036	Yes
K	0.00088	0.018	No	0.1673	0.837	No	0.0051	0.850	No	0.0945	0.315	No	0.00518	0.518	No
L	0.0023	0.046	No	0.2184	1.092	Yes	0.0492	8.200	Yes	0.1186	0.395	No	0.0285	2.850	Yes
Mean	0.00678	0.136	-	0.20149	1.007	-	0.01961	3.268	-	0.10417	0.347	-	0.02284	2.284	-
Sd	0.00533	-	-	0.04973	-	-	0.01721	-	-	0.02676	-	-	0.01711	-	-
Summary	0/12 exceed	-	-	7/12 exceed	-	-	9/12 exceed	-	-	0/12 exceed	-	-	10.12	-	-

DISCUSSION

The assessment of physicochemical properties and heavy metal concentrations in well water from Isuofia, Aguata Local Government Area, Anambra State, Nigeria, reveals significant water quality concerns, with implications for public health. The results (Tables 1.1 and 1.2) confirm three of the four study hypotheses: (1) total dissolved solids (TDS) levels exceed safe limits, (3) electrical conductivity (EC) correlates with ion concentration, and (4) heavy metals exceed WHO thresholds. The second hypothesis, that temperature affects water chemistry, is partially supported, as elevated temperatures likely influence contaminant solubility, though further investigation is needed. These findings highlight the need for urgent interventions to ensure safe drinking water in Isuofia.

Physicochemical Properties

Table 1.1 shows that 75% of samples (9/12) had alkaline pH (8.0–10.6, mean 9.42 ± 0.76), exceeding WHO/NSDWQ limits (6.5–8.5). Alkalinity, likely due to limestone dissolution in the Nanka Sand Formation or agricultural runoff, may affect taste and disinfection efficacy (Brian, 2022; Onyenweife & Imezi, 2024). TDS levels (0.47–7.78 g/L, mean 2.16 ± 1.92 g/L) exceeded the 1.0 g/L limit in 83.3% of samples, supporting hypothesis 1. High TDS, reflecting mineral dissolution and possible runoff, may cause gastrointestinal issues (Meride & Ayenew, 2016). All samples had elevated temperatures (32.0–38.5°C, mean 34.92 ± 1.94 °C), potentially increasing chemical solubility and microbial growth (O'Donnor, 2022). EC (0.005–0.118 $\mu\text{S}/\text{cm}$, mean 0.031 ± 0.030 $\mu\text{S}/\text{cm}$) remained below the 1000 $\mu\text{S}/\text{cm}$ limit, supporting hypothesis 3, as EC correlates with TDS, indicating ionic content (EPA, 2025).

Heavy Metal Concentrations

Table 1.2 indicates significant contamination, with 83.3% of samples exceeding WHO's lead limit (0.01 mg/L), 75% exceeding mercury (0.006 mg/L), and 58.3% exceeding copper (0.2 mg/L), confirming hypothesis 4. Chromium and iron remained below WHO limits (0.05 mg/L and 0.3 mg/L, respectively). Lead (0.0026–0.0622 mg/L, mean 0.02284 ± 0.01711 mg/L) and mercury (0.0040–0.0554 mg/L, mean 0.01961 ± 0.01721 mg/L) pose severe risks, including neurological and renal damage (Jamshaid et al., 2018). Copper (0.1376–0.2860 mg/L, mean 0.20149 ± 0.04973 mg/L) may cause gastrointestinal distress (WHO, 2021).

Likely Sources of Heavy Metals:

Agricultural Runoff: Lead- and mercury-based pesticides or copper-based fungicides, common in Isuofia's farming, likely infiltrate shallow wells via high rainfall (Adejuwon & Afuwape, 2018).

Waste Disposal: Improper disposal of lead-containing waste (e.g., batteries) or mercury from artisanal mining in nearby regions may contaminate groundwater (Luvhimbi et al., 2022).

Geological Weathering: Trace metals from the Nanka Sand Formation, though minimal for lead and mercury, contribute to iron and possibly copper (Onyenweife & Imezi, 2024).

Corrosion: Copper may leach from metal fittings in wells or plumbing (WHO, 2021).

Implications and Recommendations

The excesses of lead, mercury, copper, TDS, and pH indicate health risks, particularly for children, with potential for chronic diseases (WHO, 2021). To address these, we recommend: (1) point-of-use filtration to remove heavy metals and TDS, (2) routine monitoring of water quality, (3) public education on safe water practices, (4) regulation of agricultural and waste disposal practices, and (5) infrastructure upgrades to reduce corrosion. These findings highlight the need for localized water management strategies in rural Nigeria to ensure safe drinking water and support public health.

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