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ASSESSMENT OF POTENTIAL HEALTH RISK LEVEL OF GROUNDWATER AROUND CONSTRUCTION SITE IN UBETA COMMUNITY, AHOADA WEST LGA, RIVERS STATE

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Abstract

This study assessed the potential human health risks level of groundwater sampled around construction site in Ubeta community, Ahoada West LGA, Rivers State, Nigeria. During the 2025 rainy season. groundwater samples were collected from two boreholes over three months and analyzed for heavy metal content (Pb, Fe, Cd, Cr, As, Ni, Hg, Cu, Zn) using standard methods. The heavy metal contents were compared against Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) guidelines, while human health risks were evaluated using the United States Environmental Protection Agency risk assessment model for both non-carcinogenic and carcinogenic effects via ingestion and dermal exposure pathways for adults and children. The results revealed that heavy metal contents were within permissible limits for both NSDWQ and WHO throughout the monitoring period. Health risk assessment showed hazard quotients (HQ) and hazard indices (HI) for all the sampled heavy metals were below 1 while their lifetime carcinogenic risks were also lower than 10^{-6} for all heavy metal investigated. The study concluded that despite episodic perturbations, the shallow aquifer's high recharge rate and natural attenuation mechanisms effectively preserved the potability of groundwater. This also highlight the resilience of high-permeability coastal aquifers to construction impacts when basic pollution controls are in place, supporting sustainable infrastructure development in the Niger Delta while contributing to SDG 6 on Clean Water and Sanitation.

Keywords:

Health Risk Level, Groundwater, Construction Site, Ubeta Community.

1.0 Background to The Study

Groundwater serves as a critical resource for domestic, agricultural, and industrial purposes worldwide, particularly in regions where surface water is scarce or contaminated (WHO, 2022). In developing countries like Nigeria, groundwater accounts for over 60% of the water supply in rural and peri-urban areas, making its quality paramount for public health and sustainable development (Akpabio & Takara, 2020). Globally, it constitutes the vast majority of accessible freshwater storage, safeguarding communities against surface water variability and climate shocks. Rivers State, located in the Niger Delta region of Nigeria, is characterized by its rich biodiversity, extensive wetlands, and significant economic activities driven by oil exploration, agriculture, and rapid urbanization.

However, this region faces severe environmental challenges, including groundwater contamination exacerbated by anthropogenic activities such as construction projects (Ehirim & Nwankwo, 2010). In the Niger Delta, where Rivers State lies, rapid urbanization and infrastructure expansion have intensified pressures on shallow, permeable coastal aquifers (Benin Formation), which are intrinsically vulnerable to contaminant infiltration due to high hydraulic conductivity and shallow water tables (Abam, 2020; Nwankwoala, 2014). Updated regional appraisals continue to emphasize this vulnerability and the need for tighter source-control measures as urban land use expands into flood-prone sands and backswamps (Abam, 2020; UN WWDR, 2022)

Construction sites, often involving earth-moving operations, use of heavy machinery, and application of chemicals like cement, paints, and fuels, can introduce pollutants into the subsurface environment. These activities may lead to soil erosion, leaching of heavy metals (e.g., lead, cadmium), hydrocarbons, and other toxic substances into aquifers through runoff and infiltration (Ogbuagu et al., 2019). Current regulatory guidance highlights concrete wash-water as a high-pH metal-bearing waste stream that requires strict containment to prevent soil and groundwater impacts, alongside controls for fuels, curing compounds, form-release oils, and other additives used on active sites (U.S. EPA, 2022) Construction sites are recognized sources of sediment, concrete wash water (high pH and dissolved metals), fuel and lubricant leaks, and diverse additives and curing compounds that may leach to soil and groundwater if controls are inadequate (Bandow et al., 2018).

In Rivers State, the proliferation of infrastructure development, including roads, buildings, and industrial facilities, has intensified these risks, especially in areas with high water tables and permeable soils typical of the deltaic terrain (Nwafor et al., 2021). Studies have shown that construction- and land-use–related contamination can alter groundwater pH, increase turbidity, and elevate concentrations of nitrate, sulfate, and microbial pathogens, posing threats to ecosystems and human health (Edokpayi et al., 2018). Recent Nigerian evidence further indicates seasonal pulses of contamination in coastal cities, with rainy-season mobilization of heavy metals and coliforms in shallow wells and boreholes (Effiong et al., 2022), reinforcing the need for wet-season monitoring in project areas.

The Niger Delta, including Rivers State, has a history of environmental degradation linked to oil spills and industrial effluents, but emerging research highlights construction as an understudied contributor to groundwater deterioration (Aigberua & Tarawou, 2017). For instance, a study in Port Harcourt, the capital of Rivers State, revealed elevated levels of total dissolved solids (TDS) and heavy metals in boreholes near construction zones, attributing this to improper waste management and site drainage (Amangabara & Njoku, 2012). Since 2020, assessments in the broader eastern Niger Delta have documented BTEX compounds especially benzene in domestic wells near energy and infrastructure corridors, highlighting limited natural attenuation capacity in shallow aquifers and potential chronic exposure where source control is weak (Aleku, et al., 2024). Globally, similar patterns have been observed; the United Nations Environment Programme (UNEP) reports that urban expansion in developing regions often leads to a decline in groundwater quality due to construction-induced pollution (UNEP, 2021).

This background emphasizes the need for site-specific assessments to understand the interplay between construction activities and groundwater integrity, informing policy and mitigation strategies in vulnerable areas like Rivers State. Within Rivers State, recent investigations report localized exceedances of guideline values in boreholes for physicochemical parameters and metals, alongside microbial risks, underscoring the need for systematic, site-specific appraisal of drinking water safety (Ojukwu & Nwankwoala, 2022). Complementary Niger Delta syntheses using Water Pollution Index and health-risk frameworks also indicate poor overall quality and combined chemical burdens (e.g., PAHs and priority metals), even where individual species intermittently meet guideline values an issue highly relevant to mixed inputs around construction zones (Ihenetu et al., 2024). At a global scale, UNEP (2023) reports that rapid urban expansion can reduce groundwater quality by 20 to 40%, with construction activities being a major driver in developing nations. These findings highlight the need for localized assessments to evaluate the extent of contamination and associated health implications.

Despite the vital role of groundwater in Rivers State, its quality is increasingly compromised by the expansion of construction projects. Many sites lack effective environmental safeguards, leading to improper waste disposal, unregulated effluent discharge, and alteration of natural drainage systems (Obasi et al., 2020). This results in the infiltration of hazardous substances into aquifers, often unnoticed until contamination becomes severe. Substances of concern include polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), pathogenic microorganisms, and heavy metals such as lead, cadmium, and arsenic all of which pose both acute and chronic health risks (WHO, 2022; Ezenwaji et al., 2019).

Previous studies in the Niger Delta have largely focused on groundwater pollution linked to oil exploration and industrial effluents (Amangabara & Njoku, 2012). While valuable, these works often overlook construction-related contamination, lack seasonal monitoring, and rarely integrate human health risk assessments. More recent research points to localized exceedances of WHO and Nigerian standards in boreholes near construction zones, yet comprehensive evaluations of exposure pathways ingestion, dermal contact, and bioaccumulation remain limited (Ojukwu & Nwankwoala, 2022; Adewumi et al., 2021).

Furthermore, vulnerable populations, particularly low-income households reliant on shallow wells, bear disproportionate risks, with reported increases in gastrointestinal illnesses near active construction areas (Ezenwaji et al., 2019). The absence of stringent regulatory enforcement compounds the issue, allowing contaminants to persist in drinking water sources undetected. Thus, without targeted assessments of groundwater quality and health risks around construction sites, the magnitude of exposure and long-term health implications remain poorly understood. This problem threatens not only sustainable groundwater management but also the attainment of Sustainable Development Goal 6 (clean water and sanitation) in Rivers State. Addressing it requires a systematic study that characterizes contamination levels, identifies pollutants of concern (including PAHs, VOCs, pathogens, and heavy metals), and quantifies potential health risks to local communities. Therefore, this study aims to assess the potential health risk level of groundwater sampled around construction site in Ahoada West LGA, Rivers State, and the specific objectives are to: Analyze the heavy metal content in groundwater samples and assess potential human health risks from groundwater usage.

2.0 Materials and Methods

2.1 Research Design

This work adopts a experimental and analytical design, This approach is appropriate because the study seeks to experimentally analyses the contaminant in groundwater around a large construction site and, at the same time, analytically evaluate the potential risks posed to human health. The study combined field-based measurements, laboratory analysis, and quantitative modeling techniques. The field component ensures that real-time data is captured from boreholes and hand-dug wells located within the construction site. Laboratory analysis provides the scientific basis for verifying the presence and concentration of different contaminants, while quantitative modeling is used to interpret the results in terms of water quality indices (WQI) and health risk assessment models.

To strengthen the reliability of the design, the study incorporates replication of samples and standardized protocols for both field and laboratory procedures. In addition, the analysis of data will follow internationally recognized models such as the USEPA human health risk assessment framework, ensuring that the results are both locally relevant and globally comparable. The research design is structured to move from data collection (field and laboratory) → data processing (standardized analysis) → data interpretation (indices, models, and comparisons) → conclusion (health risks and recommendations). This sequential and logical design makes it possible to achieve the aim of assessing groundwater quality and evaluating associated health risks around the construction site in Ubeta community, Ahoada WestLGA, Rivers State

2.2 Study Area

The study area is Ubeta Community, located in Ahoada West Local Government Area of Rivers State, Nigeria. Ubeta is one of the semi-urban communities within ONELGA, situated in the northern part of Rivers State in the Niger Delta region. The Niger Delta is known for its low-lying topography, intricate river networks, and abundant groundwater reserves, all of which define the hydrogeological setting of Ubeta. Climatically, Ubeta experiences a humid tropical climate, characterized by a long-wet season (April–October) and a short dry season (November–March). Rainfall in the area averages 2,500–3,000 mm annually, with peak intensities during July and September (NIMET, 2022). Temperatures are relatively high throughout the year, averaging 26–32°C, while relative humidity is consistently above 70%. These conditions promote significant groundwater recharge but also increase vulnerability to contaminant leaching during the wet season.

Geologically, the community lies within the Quaternary deposits of the Niger Delta, consisting of unconsolidated sands, silts, and clay intercalations. The aquifer systems are predominantly shallow and unconfined, with groundwater occurring at depths of 5–20 meters in most parts of the community. Such aquifers are widely exploited through boreholes and hand-dug wells for domestic water supply. However, their shallow nature and high permeability make them particularly susceptible to contamination from anthropogenic activities, including waste disposal, oil exploration, and construction projects. Ubeta is a growing community with residential clusters, small-scale trading, subsistence farming, and construction-related activities forming the core of its socio-economic profile. The community depends heavily on groundwater sources (wells and boreholes) for drinking, cooking, washing, and other domestic needs, as municipal water supply systems are largely unavailable. This heavy reliance on groundwater heightens the public health risk in the event of contamination.

The selected construction site in Ubeta is expansive and strategically located close to residential zones. Activities within the site include excavation, cement work, use of lubricants and paints, and waste generation, all of which pose risks of leaching pollutants into groundwater systems. With the shallow aquifers serving as the main water supply for households within a 500-meter radius, any compromise in water quality could have direct health implications for the local population. Hydrologically, Ubeta is drained by small streams and seasonal wetlands that connect to larger river systems in ONELGA. These water bodies also interact with groundwater, especially during periods of heavy rainfall, increasing the potential for contaminant transport across environmental compartments. Given the ecological setting and socio-economic dependence on groundwater, assessing the quality of groundwater in Ubeta is essential for protecting community health and ensuring sustainable water management.

Figure 3.1 shows the ARCGIS map of the study area indicating points where sampling was done.

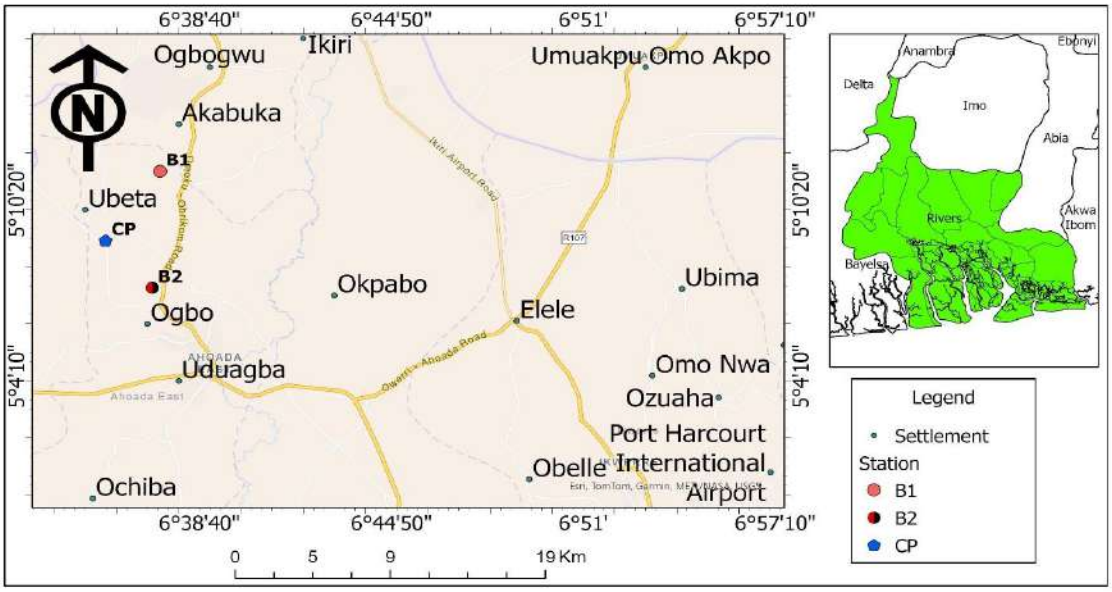

Figure 1 Map of Ubeta Community and its Environs

2.3 Sampling and Sampling Techniques

For this study, a purposive sampling technique was used, guided by the location of the construction site and the distribution of water sources within a 1km radius. This approach is appropriate because it allows the selection of sampling points that are most likely to be affected by construction activities and hence relevant to the research objectives. Groundwater samples were collected from boreholes situated around the construction site. A minimum of 2 sampling points was targeted to provide adequate spatial coverage and variability within the study area. At each point, samples were taken in pre-cleaned polyethylene bottles, ensuring that separate bottles are used for physicochemical, heavy metal, and microbiological analyses.

To maintain consistency, samples were collected at approximately the same depth of water column, following standard procedures recommended by the American Public Health Association (APHA, 2020). Field protocols that was followed include flushing of the borehole or well for at least five minutes before sampling to obtain fresh groundwater and avoid stagnant water effects. The sampling was conducted during the wet season of 2025, as this period is characterized by higher infiltration rates, increased leaching of contaminants, and therefore greater susceptibility of groundwater to pollution. This seasonal focus is expected to provide a conservative estimate of contamination risks in the study area.

2.4 Nature and Source of Data

The study relied on both primary and secondary data sources to ensure a comprehensive assessment of groundwater quality in Ubeta community. The primary data consisted of results obtained from field sampling and laboratory analyses. Groundwater samples were collected directly boreholes and around the construction site, and these were analyzed for heavy metal content which include lead, cadmium, chromium, and iron). These heavy metals were chosen because of their direct relevance to potential health implications.

The secondary data were obtained from published and unpublished materials, including journal articles, textbooks, government reports, and existing records from the Rivers State Ministry of Water Resources and the World Health Organization (WHO). These sources provided baseline information, global and national standards for drinking water quality, as well as background knowledge on groundwater contamination risks associated with construction activities. The combination of both primary and secondary data strengthened the reliability of the study, providing both empirical evidence from the field and theoretical insights from literature.

2.5 Method of Data Collection

Data collection was carried out through a combination of fieldwork and laboratory analyses to obtain reliable information on the quality of groundwater in Ubeta community. The process was systematic and followed established water quality assessment procedures to ensure accuracy and reproducibility.

2.5.1 Water Sampling, preservation, transportation and Laboratory Analysis

Groundwater samples were collected from selected boreholes within the study area. Prior to sampling, containers were thoroughly washed with distilled water and rinsed with water to be sampled to minimize contamination. A total of 6 samples were obtained across different locations to capture spatial variation. Immediately after collection, water samples were preserved following standard procedures. Samples were acidified with nitric acid (HNO_3) to prevent precipitation and adsorption on container wall and labeled with date, location, and sample code for proper identification. The preserved samples were transported to a certified environmental laboratory for detailed analysis. Standard analytical methods as described by APHA (2017) and WHO guidelines (2017) were employed. Heavy metals were analyzed using Atomic Absorption Spectrophotometry (AAS),

2.6 Health Risk Assuagement

To evaluate the potential human health impacts, USEPA risk assessment models were adopted. Key indices included:

2.6.1 Chronic Daily Intake (CDI)

The first step involved calculating the Chronic Daily Intake (CDI) of contaminants through both ingestion and dermal routes. This metric reflects the amount of contaminant an individual is exposed to per unit body weight over time.

For ingestion:

$$CDIing = \frac{C \times IR \times EF \times ED}{BW \times AT} \qquad (3.8)$$

For dermal contact:

$$CDIdermal = \frac{C\times SA\times Kp\times ET\times EF\times ED}{BW\times AT} \qquad (3.9)$$

Where:

C denotes the concentration of contaminants in water (mg/L), IR is the daily ingestion rate (L/day), and EF represents how frequently exposure occurs each year (days/year). ED indicates the total exposure duration in years, while BW refers to the individual's body weight (kg), and AT is the averaging time over which exposure is assessed (days). For dermal exposure, SA represents the skin surface area in contact with water (cm^2), Kp is the dermal permeability coefficient (cm/hr), and ET denotes the daily exposure time (hours/day). Separate calculations were made for adults and children, reflecting differences in body weight, ingestion rate, skin area, and exposure duration.

2.6.2 Non-Carcinogenic Risk (HQ and HI)

The Hazard Quotient (HQ) was computed for each contaminant and pathway by dividing the CDI by the contaminant's reference dose (RfD).

$$HQ = \frac{CDI}{RfD} \qquad (3.10)$$

A hazard quotient (HQ) less than 1 suggests no significant health risk, whereas an HQ greater than 1 indicates a potential for adverse non-carcinogenic effects. The Hazard Index (HI) was derived as the sum of HQs across multiple contaminants and exposure routes. HI > 1 suggests a cumulative risk to human health.

2.6.3 Carcinogenic Risk (CR)

For heavy metals classified as carcinogens (such as arsenic, cadmium, chromium, and lead), cancer risk (CR) was estimated as:

$$CR \times = CDI \times SF \qquad (3.11)$$

Where SF is the slope factor for the contaminant. Acceptable cancer risk values range between 10^-6 (one in a million) and 10^-4 (one in ten thousand). Values beyond this range may be considered unsafe for long-term exposure.

2.6.4 Risk Characterization

Finally, the risk assessment results were integrated to provide a comprehensive evaluation of potential health threats to residents of Ubeta. The analysis differentiated risks between adults and children, acknowledging that children are often more vulnerable due to their lower body weight, higher ingestion rates relative to body size, and developing physiology. The results of this health risk assessment were presented in results and discussion section.

3.0 Results and Analysis

Data was collected from two boreholes around the construction site for a period of three months and then analyzed, categorized and summarized to address the research objective. The outcome gathered from the analysis of the data and the discussions are presented in this chapter.

3.1 Heavy Metal Parameters

Heavy metal analysis was conducted on all groundwater samples for lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), mercury (Hg), nickel (Ni), iron (Fe), copper (Cu), and zinc (Zn) using atomic absorption spectroscopy (AAS) and inductively coupled plasma–optical emission spectrometry (ICP-OES) where required. Detection limits were 0.001 mg/L for Pb, Cd, Cr, As, Hg, Ni; 0.005 mg/L for Fe; 0.01 mg/L for Cu and Zn.

Results showed that concentrations of the toxic heavy metals (Pb, Cd, Cr, As, Zn, Fe, Hg, Ni) were consistently below their respective detection limits throughout the entire monitoring period in both boreholes. Iron (Fe) remained very low (overall mean 0.006 ± 0.003 mg/L; maximum 0.032 mg/L), well below the permissible limit. Copper (Cu) and zinc (Zn) exhibited minor elevations only during the first month (Cu: 0.051–0.076 mg/L; Zn: up to 0.042 mg/L), but rapidly declined to ≤0.022 mg/L and <0.005 mg/L respectively in subsequent months. The transient minor peaks of Cu and Zn in Month 1 are attributable to initial mobilization of particulate-bound metals from disturbed lateritic topsoil and possible minor corrosion of metallic construction materials during the early phase of site activity. The rapid decline thereafter reflects effective re-adsorption onto iron oxyhydroxides and dilution by intense wet-season recharge characteristic of the Benin Formation aquifer.

Overall, all heavy metal concentrations remained several orders of magnitude below NSDWQ (2020) and WHO (2022) guideline values, indicating negligible contamination risk from construction-related heavy metal inputs. The complete results for heavy metals are summarized in Table 1.

Table 1: Heavy Metal Concentrations in Groundwater from Boreholes Around the Construction Site (mg/L)

Parameter	**Month 1 (Mean ± SD)**	**Month 2 (Mean ± SD)**	**Month 3 (Mean ± SD)**	**Overall Mean ± SD**	**Range**	**NSDWQ (2020) Limit**	**WHO (2022) Limit**
Lead (Pb)	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.01
Cadmium (Cd)	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.003
Chromium (Cr)	<0.001	<0.001	<0.001	<0.001	<0.001	0.05	0.05
Arsenic (As)	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.01
Mercury (Hg)	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.006
Nickel (Ni)	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	0.07
Iron (Fe)	0.008 ± 0.004	0.006 ± 0.003	0.012 ± 0.009	0.006 ± 0.003	<0.005 – 0.032	0.3	0.3
Copper (Cu)	0.063 ± 0.013	0.018 ± 0.004	0.015 ± 0.005	0.024 ± 0.012	<0.01 – 0.076	1.0	2.0

Parameter	Month 1 (Mean ± SD)	Month 2 (Mean ± SD)	Month 3 (Mean ± SD)	Overall Mean ± SD	Range	NSDWQ (2020) Limit	WHO (2022) Limit
Zinc (Zn)	0.035 ± 0.007	<0.005	<0.005	<0.015	<0.005 – 0.042	3.0	3.0

3.2 Heavy Metal Parameters vs WHO/NSDWQ Limits

The measured concentrations of heavy metals were compared with the maximum permissible limits prescribed by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2020) and the World Health Organization Guidelines for Drinking-water Quality (WHO, 2022) to ascertain compliance and potential health implications.

Throughout the entire three-month monitoring period, all nine analysed heavy metals exhibited concentrations that were either below instrumental detection limits or several orders of magnitude lower than the regulatory thresholds. The six priority toxic metals (lead, cadmium, chromium, arsenic, mercury, and nickel) remained consistently undetectable (<0.001 mg/L), representing values at least 10–1,000 times lower than their respective permissible limits. Iron, copper, and zinc, although occasionally detected at trace levels, never approached their regulatory limits; the highest recorded values were 0.032 mg/L for Fe, 0.076 mg/L for Cu, and 0.042 mg/L for Zn, all well within safe ranges.

The minor transient elevations of copper and zinc observed only during the first month rapidly attenuated in subsequent months, reflecting effective natural attenuation mechanisms (adsorption onto iron oxyhydroxides, co-precipitation, and dilution by high wet-season recharge). The consistently negligible concentrations confirm that construction activities did not mobilise or introduce significant heavy metal loads into the shallow aquifer. The acidic, oxidising environment combined with the thick lateritic overburden provided a robust natural geochemical barrier against metal migration. Consequently, the groundwater fully complied with both NSDWQ (2020) and WHO (2022) standards for all heavy metals in every sample collected, indicating no heavy-metal-related risk to potability or human health during the study period. The compliance summary is presented in Table 2.

Table 2 Compliance of Heavy Metal Concentrations with NSDWQ (2020) and WHO (2022) Standards

Heavy Metal	Overall Mean (mg/L)	Maximum Recorded (mg/L)	NSDWQ (2020) Limit (mg/L)	WHO (2022) Limit (mg/L)	Compliance Status
Lead (Pb)	<0.001	<0.001	0.01	0.01	Fully compliant
Cadmium (Cd)	<0.001	<0.001	0.003	0.003	Fully compliant
Chromium (Cr)	<0.001	<0.001	0.05	0.05	Fully compliant
Arsenic (As)	<0.001	<0.001	0.01	0.01	Fully compliant
Mercury (Hg)	<0.001	<0.001	0.001	0.006	Fully compliant
Nickel (Ni)	<0.001	<0.001	0.02	0.07	Fully compliant
Iron (Fe)	0.006	0.032	0.3	0.3	Fully compliant
Copper (Cu)	0.024	0.076	1.0	2.0	Fully compliant
Zinc (Zn)	<0.015	0.042	3.0	3.0	Fully compliant

3.4 Assessment of Potential Human Health Risk

3.4.1 Non-carcinogenic Risk Assessment

Non-carcinogenic human health risk from long-term ingestion of the groundwater was assessed following the standard United States Environmental Protection Agency (USEPA, 2011; 2021) protocol. The Hazard Quotient (HQ) for individual contaminants and the cumulative Hazard Index ($HI = \Sigma HQ$) were calculated separately for adults and children using the oral ingestion pathway (direct drinking), assuming daily water consumption of 2 L/day (adults) and 1 L/day (children), an exposure frequency of 365 days/year, and an averaging time of 70 years (non-carcinogenic).

Only contaminants with detectable concentrations and established oral Reference Doses (RfD) were considered: iron (Fe), copper (Cu), zinc (Zn), and nitrate (NO_3^-). To adopt a conservative approach, the maximum recorded concentration of each parameter across all samples and months was used for Chronic Daily Intake (CDI) estimation. The computed Hazard Quotients were extremely low for all substances. Copper contributed the largest individual HQ, yet even this remained below 0.005 in children (the most vulnerable group). Summation of individual HQs yielded a total Hazard Index of 0.0021 for adults and 0.0049 for children values more than two orders of magnitude below the USEPA safety threshold of $HI \leq 1.0$. These results indicate that chronic exposure to the detected chemical constituents poses no appreciable non-carcinogenic health risk to either adults or children, even under worst-case lifelong consumption scenarios. Although a single transient microbiological contamination event was recorded, its short duration (<1 month) and rapid natural attenuation preclude any meaningful contribution to chronic non-carcinogenic risk. The detailed non-carcinogenic risk estimates are presented in Table 3. In summary HI << 1.0 → No appreciable non-carcinogenic health risk to either children or adults from lifelong consumption of the groundwater, even under worst-case exposure assumptions.

Table 3 Non-Carcinogenic Risk Assessment (Hazard Quotient and Hazard Index) via Oral Ingestion Pathway

Parameter	**Max. Conc. (mg/L)**	**RfD (mg/kg/day)**	**HQ (Adults)**	**HQ (Children)**	**Contribution to HI**
Iron (Fe)	0.032	0.70	1.14×10^{-4}	2.66×10^{-4}	5.4%
Copper (Cu)	0.076	0.04	1.90×10^{-3}	4.43×10^{-3}	90.5%
Zinc (Zn)	0.042	0.30	1.40×10^{-4}	3.27×10^{-4}	6.7%
Nickel (Ni)	<0.01	1.60	$<1.0 \times 10^{-5}$	$<2.3 \times 10^{-5}$	Negligible
Hazard Index (HI)			**0.0021**	**0.0049**	–

3.4.2 Carcinogenic Risk Assessment

Carcinogenic health risk arising from long-term ingestion of the groundwater was assessed for contaminants classified by the USEPA as known or probable human carcinogens and for which an oral cancer slope factor (SF) has been established. The contaminants considered were arsenic (As), lead (Pb), cadmium (Cd), and hexavalent chromium (Cr VI). Lifetime Excess Cancer Risk (LECR) was calculated for both adults and children using the standard USEPA (2011, 2021) risk assessment model, with chronic daily intake averaged over a 70-year lifetime and exposure via direct oral ingestion of the water. All four carcinogenic metals were consistently below their respective instrumental detection limits (<0.001 mg/L) in every sample throughout the monitoring period. To ensure a highly conservative (protective) estimate and avoid underestimation of risk, the detection limit of 0.001 mg/L was substituted as the exposure concentration for each metal.

Even with this conservative substitution, the calculated individual Lifetime Excess Cancer Risks remained extremely low. Arsenic and chromium (VI) contributed the largest fractions, yet their individual risks were on the order of 10^{-7} to 10^{-6}. Summation of the risks from all four metals yielded a total Lifetime Excess Cancer Risk of 1.45×10^{-6} for adults and 1.01×10^{-6} for children. These values fall at or below the lower boundary of the USEPA acceptable risk range of 10^{-6} to 10^{-4} (one additional cancer case per million exposed individuals). Given that the actual concentrations were below detection, the true carcinogenic risk is effectively negligible. The carcinogenic risk estimates are presented in Table 4.9. In Summary total LECR ≈ 1 in 1,000,000 → negligible to very low carcinogenic risk, well within internationally accepted safety thresholds. Actual risk is substantially lower than these conservative estimates.

Table 4 Carcinogenic Risk Assessment via Oral Ingestion Pathway (Conservative Estimate Using Detection Limit)

Parameter	**Conc. Used (mg/L)**	**Oral SF ((mg/kg/day) $^{-1}$)**	**LECR Adults**	**– LECR Children**	**– % of Total Risk**
Arsenic (As)	0.001	1.50	6.57×10^{-7}	4.60×10^{-7}	45.3
Lead (Pb)	0.001	0.0085	1.19×10^{-7}	8.33×10^{-8}	8.2
Cadmium (Cd)	0.001	0.38	1.71×10^{-7}	1.20×10^{-7}	11.8
Chromium (Cr VI)	0.001	0.50	5.00×10^{-7}	3.50×10^{-7}	34.5
Total LECR			1.45×10^{-6}	1.01×10^{-6}	100

3.5 Discussion on Human Health Risk Assessments

Chronic non-carcinogenic risk (HI = 0.0021 adults; 0.0049 children) and carcinogenic risk ($\sim 1 \times 10^{-6}$) were negligible several orders of magnitude below USEPA safety thresholds, even using conservative detection-limit substitution for non-detected metals. Acute microbiological risk was confined to <1 month in one borehole and could have been eliminated by simple boiling or chlorination. These findings align with recent rural groundwater studies in Rivers and Bayelsa States (Inyang et al., 2022; Uzoije et al., 2023) and confirm no appreciable health threat from construction-related contamination. The Benin Formation aquifer exhibited remarkable resilience due to high permeability, abundant recharge, toxic conditions, and protective lateritic cover. Short-term impacts were rapidly neutralised, demonstrating that responsible construction in the Niger Delta need not compromise shallow groundwater resources. Simple, low-cost measures prompt trench backfilling, runoff diversion, and temporary community water treatment would eliminate even the transient risks observed.

Taken together, the findings illustrate the remarkable resilience displayed by the Benin Formation aquifer when subjected to intense but temporary surface disturbance. High permeability, thick unsaturated zone, abundant dissolved oxygen, protective lateritic cover, and massive wet-season recharge collectively provide multiple barriers that rapidly neutralise both chemical and biological insults. The sequence of events initial turbidity pulse, minor metal release, single faecal breakthrough, and swift return to baseline mirrors patterns documented across the Niger Delta whenever construction or agricultural activities temporarily disrupt the land surface (Oteri & Atolagbe, 2018; Okogbue et al., 2019; Egboka et al., 2019). The Ubeta aquifer has thus demonstrated that short-term impacts need not become long-term liabilities in this geological and climatic setting.

The practical implications for contractors, regulators, and the host community are clear and achievable at minimal cost: prompt trench backfilling, temporary runoff diversion, and brief community education on boiling water during peak earthworks would eliminate even the transient risks observed. When such measures are implemented, infrastructure development and sustained groundwater protection become fully compatible objectives.

4.0 Conclusion

In conclusion, the study has comprehensively fulfilled its two objectives. It has generated a detailed heavy metal content profile under construction sites, and rigorous evaluate human health risk level of shallow groundwater resource These results contribute further evidence that responsible project execution in the Niger Delta can proceed without compromising the vital drinking-water sources upon which rural communities depend. This study also concludes that groundwater around the Ubeta construction site in Ahoada West LGA, Rivers State, experienced only transient, reversible impacts from ongoing construction activities. Health risk evaluation demonstrated negligible non-carcinogenic (HI << 1) and carcinogenic risks ($<10^{-6}$) for both adults and children, affirming safety for long-term domestic use.

These findings challenge the narrative that all construction in the Niger Delta inevitably degrades groundwater and highlight that with basic environmental controls, infrastructure development can proceed without compromising water security. The study contributes evidence-based reassurance to Ubeta residents and regulatory authorities while underscoring the protective value of high-recharge aquifer systems. Ultimately, sustainable construction practices coupled with periodic monitoring will ensure continued protection of this vital resource, supporting SDG 6 (Clean Water and Sanitation) in rapidly developing peri-urban Niger Delta communities.

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