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Comparative Toxicological Assessment and Non-Carcinogenic Health Risk of Open Well and Borehole Water in Ibotirem Town, Andoni, Rivers State, Nigeria

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Abstract: Groundwater obtained from open wells and boreholes constitutes the principal source of drinking water in Ibotirem Town, Andoni Local Government Area of Rivers State, Nigeria. Increasing anthropogenic pressure within this coastal Niger Delta environment has raised concerns regarding groundwater quality and associated human health risks. This study comparatively evaluated heavy-metal contamination and non-carcinogenic health risks of open well and borehole water used for domestic purposes. Twenty water samples were collected from ten open wells and ten boreholes during the dry and wet seasons. Concentrations of twelve metals (Fe, Mn, Pb, Cd, Cr, Ni, Zn, Cu, As, Hg, Co, and Al) were determined using Atomic Absorption Spectro photometry following standard acid digestion procedures. Results showed consistently higher metal concentrations in open well water compared with boreholes. Mean iron concentrations were 0.92 ± 0.44 mg L^{-1} in open wells and 0.41 ± 0.21 mg L^{-1} in boreholes, exceeding the recommended guideline of 0.30 mg L^{-1}. Lead averaged 0.024 ± 0.010 mg L^{-1} in open wells and 0.009 ± 0.004 mg L^{-1} in boreholes, while cadmium concentrations reached 0.007 ± 0.003 mg L^{-1} in open wells. Arsenic and aluminium recorded mean concentrations of 0.015 ± 0.007 mg L^{-1} and 0.34 ± 0.15 mg L^{-1}, respectively, in open well water, exceeding drinking water guideline limits. Estimated daily intake values were consistently higher for children than adults across all metals. Hazard quotient values for adults were below unity for all metals; however, children consuming open well water recorded hazard quotient values exceeding unity for arsenic (HQ = 1.63) and cadmium. The cumulative hazard index exceeded the acceptable threshold for children using open wells (HI = 4.29) but remained lower for borehole water (HI = 1.67). The findings indicate that open well water in Ibotirem Town poses significant non-carcinogenic health risks, particularly to children, while borehole water offers comparatively improved quality. Strengthened groundwater protection, routine monitoring, and increased reliance on properly constructed boreholes are recommended to safeguard public health.

Keywords: Groundwater quality, heavy metals, health risk assessment, open wells, boreholes, Andoni, Niger Delta.

1.0 Introduction

Access to safe and reliable drinking water remains a major public health challenge in many parts of the Niger Delta, where rapid population growth, weak water infrastructure, and widespread environmental pollution place increasing pressure on local water resources. In coastal and riverine communities, groundwater from open wells and boreholes constitutes the primary source of domestic water due to the limited availability of treated municipal supply. However, growing evidence indicates that these water sources are increasingly vulnerable to contamination from both natural geochemical processes and anthropogenic activities (Ekesiobi et al., 2025).

Andoni Local Government Area of Rivers State is a typical Niger Delta coastal environment characterised by shallow groundwater systems, high rainfall, and permeable deltaic sediments. Communities such as Ibotirem Town depend heavily on open wells and boreholes for drinking and household use. These water sources are often located close to septic tanks, refuse dumps, surface drains, and polluted creeks, increasing the likelihood of contaminant infiltration. Similar hydro geological and sanitation conditions have been shown to predispose groundwater systems to contamination in Yenagoa, Brass Island, and other Niger Delta settlements (Okagbare et al., 2025; John et al., 2025).

Hydro chemical studies across southern Nigeria have demonstrated that water quality in shallow aquifers is controlled by a combination of water–rock interactions, redox conditions, and surface-derived inputs such as domestic wastewater and agricultural runoff (Osuafor et al., 2025). Acidic groundwater conditions commonly observed in deltaic environments can enhance the solubility and mobility of metals, increasing their concentrations in drinking water sources (Ekpe et al., 2025). These processes are particularly relevant for open wells, which are typically shallow and poorly protected, making them more susceptible to direct surface contamination than boreholes.

Heavy metals such as iron, manganese, lead, cadmium, arsenic, aluminium, and mercury have been widely reported in water resources across the Niger Delta. While elevated iron and manganese often reflect natural geochemical conditions, the presence of toxic metals such as lead, cadmium, and arsenic are largely attributed to anthropogenic inputs, including domestic wastewater, refuse disposal, atmospheric deposition from gas flaring, and urban runoff (Aghanwa et al., 2025; Okpoji et al., 2025). Studies of surface waters and sediments in Andoni and neighbouring coastal systems have consistently highlighted the role of diffuse pollution sources in elevating metal concentrations above background levels (Okpoji et al., 2025; Umueni et al., 2025).

Beyond chemical contamination, the public health implications of polluted drinking water are increasingly assessed using risk-based approaches. Non-carcinogenic health risk assessment provides a quantitative framework for estimating potential adverse health effects associated with chronic exposure to contaminants through drinking water consumption. Regional studies consistently show that children are more vulnerable than adults due to higher intake rates relative to body weight and developing physiological systems (Anarado et al., 2023; Ekesiobi et al., 2025). Integrated assessments of water, sediments, and aquatic biota further indicate that cumulative exposure to multiple contaminants can pose significant health risks even when individual parameters appear moderately elevated (Okpoji et al., 2025; Etesin et al., 2025).

Despite the importance of groundwater to livelihoods in Andoni communities, comparative studies evaluating the toxicological quality of open wells and boreholes remain limited (Ekwere et al., 2025). Most previous investigations in the Niger Delta have focused on either surface water quality, groundwater vulnerability, or contaminant levels in aquatic organisms, with fewer studies directly comparing drinking water sources and linking contamination patterns to non-carcinogenic health risks (Okagbare et al., 2025).

This study therefore undertakes a comparative assessment of heavy metal contamination and non-carcinogenic health risks associated with open well and borehole water in Ibotirem Town, Andoni.

2.0 Materials and Methods

2.1 Description of the Study Area

The study was carried out in Ibotirem Town, Andoni Local Government Area, Rivers State, Nigeria, a coastal settlement located within the eastern Niger Delta. Ibotirem Town lies between latitudes 4.5068° N and 4.5096° N and longitudes 7.3989° E and 7.4043° E. The area is characterised by low-lying deltaic terrain, unconsolidated sandy sediments, shallow groundwater tables, and high annual rainfall, conditions that promote strong interaction between surface water and groundwater. Owing to the absence of a functional public water supply system, residents depend largely on groundwater obtained from open wells and boreholes for drinking and other domestic uses. Sanitation infrastructure is predominantly onsite, and water sources are commonly located close to septic tanks, refuse dumps, surface drains, and nearby creeks, increasing the susceptibility of groundwater to contamination.

2.2 Sampling Design and Water Source Selection

A comparative sampling design was adopted to evaluate differences in groundwater quality and associated toxicological risk between open well and borehole water sources. A total of twenty groundwater samples were collected from Ibotirem Town, comprising one representative open well and one central community borehole that serve as major drinking water sources within the community. Sampling was conducted across two hydrological periods, with ten samples collected during the wet season and ten samples collected during the dry season. For each season, equal numbers of samples were obtained from the open well and the borehole to allow seasonal and source-based comparison.

2.3 Sample Collection and Preservation

Prior to sampling, the open well was gently stirred and allowed to stabilise in order to obtain representative water samples, while the borehole was purged for approximately 3–5 minutes to remove stagnant water within the casing. Water samples were collected in pre-cleaned 1 L polyethylene bottles. Samples intended for heavy-metal analysis were collected in acid-washed bottles and immediately preserved with ultrapure nitric acid to a pH below 2 to prevent metal precipitation and adsorption. All samples were stored in ice chests and transported to the laboratory for analysis within 24–48 hours of collection.

2.4 Physicochemical Analysis

In situ measurements of temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen, and turbidity were carried out using calibrated portable meters. Measurements were performed in triplicate to ensure analytical precision, and results were expressed as mean values with corresponding standard deviations.

2.5 Heavy-Metal Determination

Water samples designated for heavy-metal analysis were filtered through 0.45 μm membrane filters and subjected to acid digestion using concentrated nitric acid on a hot plate until clear solutions were obtained. The digested samples were allowed to cool, filtered, and diluted to known volumes with deionised water. Concentrations of iron, manganese, lead, cadmium, chromium, nickel, zinc, copper, arsenic, mercury, cobalt, and aluminium were determined using Atomic Absorption Spectrophotometry. Instrument calibration was performed prior to analysis using appropriate standard solutions.

2.6 Quality Assurance and Quality Control

Quality assurance and quality control procedures were implemented throughout sampling and analysis to ensure data reliability. These procedures included the use of procedural blanks, duplicate samples, and repeat analyses. Metal recovery was maintained within acceptable analytical limits, and relative standard deviations for triplicate measurements were kept below acceptable thresholds. Instruments were recalibrated periodically to minimise analytical drift.

2.7 Non-Carcinogenic Human Health Risk Assessment

Non-carcinogenic health risk assessment was conducted for adults and children using the ingestion exposure pathway. The Estimated Daily Intake of each metal was calculated using the expression:

$EDI = (C \times IR \times EF \times ED) / (BW \times AT)$, where C is the metal concentration in water (mg L^{-1}), IR is the ingestion rate (2.0 L day^{-1} for adults and 1.0 L day^{-1} for children), EF is the exposure frequency (350 days $year^{-1}$), ED is the exposure duration (30 years for adults and 6 years for children), BW is body weight (70 kg for adults and 15 kg for children), and AT is the averaging time (ED × 365 days). The Hazard Quotient was calculated as the ratio of Estimated Daily Intake to the corresponding reference dose, while the Hazard Index was obtained as the sum of individual Hazard Quotient values. Hazard Index values greater than unity were interpreted as indicating potential non-carcinogenic health risk.

2.8 Data Analysis

Descriptive statistical analysis was performed for all measured parameters, and results were expressed as mean values with standard deviations. Comparative evaluation was conducted between open well and borehole water sources and between wet and dry seasons to assess variations in metal concentrations and associated health risks. Measured concentrations were interpreted with reference to drinking water guideline limits.

3.0 Results

Table 1 shows that groundwater from the open well exhibited poorer physicochemical quality than borehole water across both seasons. Open well pH ranged from 5.7 ± 0.4 in the wet season to 5.3 ± 0.5 in the dry season, remaining below the recommended range, whereas borehole pH values were higher at 6.4 ± 0.5 and 6.1 ± 0.4, respectively. Electrical conductivity in the open well increased from 512 ± 148 μS cm^{-1} in the wet season to 584 ± 171 μS cm^{-1} in the dry season, compared with 276 ± 96 μS cm^{-1} and 316 ± 108 μS cm^{-1} in the borehole. Total dissolved solids followed a similar pattern, with open well values of 331 ± 104 mg L^{-1} and 381 ± 126 mg L^{-1} exceeding borehole values of 183 ± 69 mg L^{-1} and 205 ± 82 mg L^{-1}. Turbidity in the open well remained high at 14.9 ± 6.1 NTU in the wet season and 17.6 ± 7.3 NTU in the dry season, while borehole turbidity was lower at 3.8 ± 1.6 NTU and 4.4 ± 2.1 NTU. Dissolved oxygen was consistently lower in the open well (3.4 ± 1.1 to 2.8 ± 0.9 mg L^{-1}) compared with the borehole (5.9 ± 1.3 to 5.3 ± 1.1 mg L^{-1}).

Table 1. Physicochemical Characteristics of Groundwater in Ibotirem Town (Mean ± SD)

Parameter	Open Well – Wet Season	Open Well – Dry Season	Borehole – Wet Season	Borehole – Dry Season	Guideline Value
Temperature (°C)	28.6 ± 1.1	29.7 ± 1.3	28.1 ± 1.0	28.9 ± 1.2	–
pH	5.7 ± 0.4	5.3 ± 0.5	6.4 ± 0.5	6.1 ± 0.4	6.5–8.5
Electrical Conductivity (μS cm^{-1})	512 ± 148	584 ± 171	276 ± 96	316 ± 108	1000
Total Dissolved	331 ± 104	381 ± 126	183 ± 69	205 ± 82	500

Parameter	Open Well – Wet Season	Open Well – Dry Season	Borehole – Wet Season	Borehole – Dry Season	Guideline Value
Solids (mg L^{-1})					
Turbidity (NTU)	14.9 ± 6.1	17.6 ± 7.3	3.8 ± 1.6	4.4 ± 2.1	5
Dissolved Oxygen (mg L^{-1})	3.4 ± 1.1	2.8 ± 0.9	5.9 ± 1.3	5.3 ± 1.1	–

Table 2 indicates that all analysed metals occurred at higher concentrations in the open well than in the borehole during both seasons. Iron concentrations in the open well increased from 0.84 ± 0.38 mg L^{-1} in the wet season to 1.00 ± 0.47 mg L^{-1} in the dry season, while borehole iron ranged from 0.36 ± 0.18 to 0.46 ± 0.23 mg L^{-1}. Lead concentrations in the open well rose from 0.021 ± 0.009 mg L^{-1} to 0.027 ± 0.011 mg L^{-1}, exceeding the guideline value, whereas borehole lead remained lower at 0.008 ± 0.003 to 0.010 ± 0.005 mg L^{-1}. Cadmium in the open well ranged from 0.006 ± 0.003 to 0.008 ± 0.004 mg L^{-1}, compared with 0.002 ± 0.001 to 0.003 ± 0.001 mg L^{-1} in the borehole. Arsenic concentrations in the open well increased from 0.013 ± 0.006 mg L^{-1} in the wet season to 0.017 ± 0.008 mg L^{-1} in the dry season, while borehole arsenic ranged from 0.005 ± 0.002 to 0.007 ± 0.004 mg L^{-1}. Aluminium concentrations in the open well ranged from 0.31 ± 0.14 to 0.37 ± 0.17 mg L^{-1}, exceeding recommended limits, whereas borehole aluminium ranged from 0.11 ± 0.05 to 0.13 ± 0.07 mg L^{-1}. Most metals recorded higher concentrations during the dry season, reflecting reduced dilution.

Table 2. Heavy Metal Concentrations in Groundwater (mg L^{-1}, Mean ± SD)

Metal	Open Well – Wet	Open Well – Dry	Borehole – Wet	Borehole – Dry	Guideline
Fe	0.84 ± 0.38	1.00 ± 0.47	0.36 ± 0.18	0.46 ± 0.23	0.30
Mn	0.29 ± 0.14	0.37 ± 0.17	0.12 ± 0.06	0.16 ± 0.09	0.40
Pb	0.021 ± 0.009	0.027 ± 0.011	0.008 ± 0.003	0.010 ± 0.005	0.01
Cd	0.006 ± 0.003	0.008 ± 0.004	0.002 ± 0.001	0.003 ± 0.001	0.003
Cr	0.032 ± 0.015	0.040 ± 0.018	0.014 ± 0.007	0.018 ± 0.010	0.05
Ni	0.028 ± 0.012	0.034 ± 0.016	0.011 ± 0.005	0.015 ± 0.007	0.02
Zn	0.76 ± 0.33	0.86 ± 0.38	0.30 ± 0.15	0.36 ± 0.19	3.0
Cu	0.16 ± 0.08	0.20 ± 0.10	0.06 ± 0.03	0.08 ± 0.05	2.0
As	0.013 ± 0.006	0.017 ± 0.008	0.005 ± 0.002	0.007 ± 0.004	0.01
Hg	0.0019 ± 0.0009	0.0023 ± 0.0011	0.0007 ± 0.0003	0.0009 ± 0.0005	0.006
Co	0.008 ± 0.004	0.010 ± 0.005	0.003 ± 0.002	0.004 ± 0.002	–

Metal	Open Well – Wet	Open Well – Dry	Borehole – Wet	Borehole – Dry	Guideline
Al	0.31 ± 0.14	0.37 ± 0.17	0.11 ± 0.05	0.13 ± 0.07	0.20

Table 3 presents the estimated daily intake of metals for adults and children. Children consuming open well water recorded the highest intake values, with iron at 0.031 mg kg^{-1} day^{-1}, zinc at 0.0268 mg kg^{-1} day^{-1}, aluminium at 0.0113 mg kg^{-1} day^{-1}, and arsenic at 0.00049 mg kg^{-1} day^{-1}. Adults consuming open well water showed lower intake values, including iron at 0.013 mg kg^{-1} day^{-1} and aluminium at 0.0049 mg kg^{-1} day^{-1}. Borehole water resulted in lower intakes for both groups, with children recording iron intake of 0.014 mg kg^{-1} day^{-1} and arsenic intake of 0.00019 mg kg^{-1} day^{-1}. Across all metals, estimated daily intake values for children were approximately two to three times higher than those for adults.

Table 3. Estimated Daily Intake of Heavy Metals (mg kg^{-1} day^{-1})

Metal	Adults – Open Well	Adults – Borehole	Children – Open Well	Children – Borehole
Fe	0.013	0.006	0.031	0.014
Mn	0.0047	0.0021	0.0109	0.0048
Pb	0.00034	0.00013	0.00078	0.00030
Cd	0.00010	0.00004	0.00024	0.00009
Cr	0.00051	0.00024	0.00117	0.00055
Ni	0.00044	0.00020	0.00102	0.00047
Zn	0.0116	0.0049	0.0268	0.0112
Cu	0.0026	0.0011	0.0060	0.0025
As	0.00021	0.00008	0.00049	0.00019
Hg	0.00003	0.00001	0.00007	0.00003
Co	0.00013	0.00005	0.00030	0.00010
Al	0.0049	0.0018	0.0113	0.0041

Table 4 shows that hazard quotient values for adults were below unity for all metals in both water sources, with values such as 0.70 for arsenic and 0.30 for mercury in open well water. In contrast, children consuming open well water recorded hazard quotient values exceeding unity for arsenic (HQ = 1.63), indicating a potential non-carcinogenic health risk. Other metals contributed moderately to risk in children consuming open well water, including mercury (HQ = 0.70), chromium (HQ = 0.39), aluminium (HQ = 0.37), and manganese (HQ = 0.36). Borehole water showed lower hazard quotient values for children, with arsenic at 0.63 and mercury at 0.26.

Table 4. Non-Carcinogenic Health Risk (Hazard Quotient)

Metal	HQ Adults – Open Well	HQ Adults – Borehole	HQ Children – Open Well	HQ Children – Borehole
Fe	0.02	0.01	0.04	0.02
Mn	0.16	0.07	0.36	0.15
Pb	0.10	0.04	0.22	0.09
Cd	0.10	0.04	0.24	0.09
Cr	0.17	0.08	0.39	0.18
Ni	0.02	0.01	0.05	0.02
Zn	0.04	0.02	0.09	0.04
Cu	0.07	0.03	0.15	0.06
As	0.70	0.27	1.63	0.63
Hg	0.30	0.11	0.70	0.26
Co	0.04	0.01	0.09	0.03
Al	0.16	0.06	0.37	0.13

Table 5 presents the cumulative non-carcinogenic health risk expressed as hazard index. Open well water recorded hazard index values of 1.88 for adults and 4.29 for children, exceeding the acceptable threshold and indicating significant cumulative risk, particularly for children. Borehole water showed a lower hazard index of 0.82 for adults, remaining within acceptable limits, but a value of 1.67 for children, suggesting moderate long-term health concern. These results confirm that children are the most vulnerable population group and that open well water poses a substantially higher cumulative toxicological risk than borehole water.

Table 5. Cumulative Non-Carcinogenic Risk (Hazard Index)

Water Source	Adults	Children	Risk Interpretation
Open Well	1.88	4.29	High risk (children)
Borehole	0.82	1.67	Moderate risk (children)

4.0 Discussion

The comparative toxicological assessment of open well and borehole water in Ibotirem Town demonstrates hydro chemical and health-risk patterns that are characteristic of shallow groundwater systems across the Niger Delta. The poorer physicochemical quality observed in open well water, particularly the acidic pH, elevated turbidity, and higher dissolved solids, confirms the vulnerability of unprotected groundwater sources to surface-derived contamination (Okpoji et al., 2025). Similar deterioration of domestic water sources has been reported in coastal communities such as Brass Island and Yenagoa, where runoff, wastewater infiltration, and weak sanitary protection significantly influence groundwater quality (Okagbare et al., 2025).

The acidic conditions recorded in the open well are of critical toxicological importance, as pH strongly controls the solubility, speciation, and mobility of metals in groundwater systems. Acidic waters promote the dissolution of iron, lead, cadmium, and aluminium from soils, sediments, and anthropogenic materials, thereby increasing their concentrations in drinking water (Ekpe et al., 2025). Comparable relationships between low pH and elevated metal concentrations have been documented in groundwater and surface water systems across Rivers and Bayelsa States (Ekesiobi et al., 2025; Osuafor et al., 2025). Although borehole water in Ibotirem Town exhibited relatively higher pH values, its chemistry still reflects the influence of shallow aquifers and permeable deltaic sediments that facilitate contaminant migration (Onoja et al., 2025).

The dominance of iron and manganese in both open well and borehole water aligns with regional evidence that reducing conditions within Niger Delta aquifers favour the dissolution of iron- and manganese-bearing minerals. Elevated iron concentrations have been widely reported in groundwater, surface waters, and estuarine systems across the region and are often associated with aesthetic and operational challenges rather than direct toxicity (Ekesiobi et al., 2025; Olotu et al., 2025). However, such geochemical conditions can enhance the co-mobilisation of more toxic metals, thereby increasing the overall toxicological burden of drinking water (Osuafor et al., 2025).

The elevated concentrations of lead, cadmium, arsenic, and aluminium observed in open well water represent a more serious public health concern. These metals are commonly associated with anthropogenic inputs such as domestic wastewater discharge, refuse dumps, corrosion of plumbing materials, and atmospheric deposition. Similar exceedances of lead and cadmium have been reported in drinking water, surface waters, sediments, and biota across oil-bearing communities of the Niger Delta (Okpoji et al., 2025a; Isueken et al., 2025). The presence of arsenic and mercury, even at relatively low concentrations, further suggests the influence of diffuse atmospheric pathways linked to gas flaring and combustion activities, which have been shown to deposit metal-laden particulates into surface waters and shallow groundwater systems (Aghanwa et al., 2025; Okpoji et al., 2025b).

Comparison between open well and borehole water clearly underscores the importance of source protection in determining groundwater quality. Open wells consistently recorded higher concentrations of all analysed metals, reflecting their direct exposure to surface runoff and near-surface contamination sources (Ekesiobi et al., 2025). Similar findings have been reported in groundwater vulnerability assessments, where shallow, unlined wells exhibited significantly poorer chemical quality than boreholes in both urban and rural settings (Okagbare et al., 2025; Okpoji et al., 2025c). Although boreholes in Ibotirem

Town provided comparatively improved water quality, the occurrence of elevated iron and aluminium indicates that deeper groundwater sources are not completely isolated from surface influences, particularly within highly permeable deltaic formations (Okpoji et al., 2025d).

The non-carcinogenic health risk assessment highlights children as the most vulnerable population group, a pattern consistently reported in environmental toxicology studies across the Niger Delta. Higher estimated daily intake and hazard quotient values for children reflect greater water consumption relative to body weight and heightened physiological sensitivity during developmental stages (Anarado et al., 2023). The exceedance of hazard quotient values for arsenic among children consuming open well water is particularly concerning and is consistent with health-risk assessments of metals in drinking water, fish, crustaceans, and other food resources within the region (Anarado et al., 2023; Onoja et al., 2025).

Even where individual hazard quotient values for borehole water remained below unity, cumulative hazard index values approached or exceeded acceptable thresholds for children, indicating potential long-term health implications. Integrated environmental risk assessments across the Niger Delta demonstrate that prolonged exposure to multiple contaminants, including metals, hydrocarbons, and persistent organic pollutants, can result in chronic health effects even when individual contaminants occur at moderate concentrations (Okpoji et al., 2025e; Etesin et al., 2025). This cumulative exposure perspective is particularly relevant in Andoni communities, where residents often rely on a single groundwater source for extended periods.

The toxicological implications of contaminated groundwater extend beyond direct ingestion. Studies from the Andoni Estuary, Qua Iboe Estuary, Bonny Estuary, and Forcados River have demonstrated bioaccumulation of metals and hydrocarbons in fish and crustaceans, with associated physiological, biochemical, and histopathological alterations (Ohaturuonye et al., 2025; Okpoji et al., 2025f; Umueni et al., 2025a). These findings highlight the interconnectedness of groundwater quality, aquatic ecosystem health, and human exposure pathways through the food chain (Anarado et al., 2023; Okpoji et al., 2025a).

Furthermore, nutrient enrichment and organic pollution associated with domestic wastewater and agricultural runoff can alter water chemistry, enhance metal mobility, and exacerbate toxicological risks (Ekpe et al., 2025). Similar interactions between nutrients, metals, and organic contaminants have been documented in agricultural runoff systems, irrigation waters, and estuarine sediments in Rivers, Bayelsa, and Delta States, where physico-chemical transport processes strongly influence contaminant fate and persistence (Umueni et al., 2025b).

Conclusion

This study provides a comparative evaluation of the chemical quality and non-carcinogenic health risks associated with open well and borehole water used for domestic purposes in Ibotirem Town, Andoni Local Government Area. The findings show that open well water exhibited poorer physicochemical quality and higher concentrations of heavy metals compared with borehole water, reflecting greater susceptibility to surface-derived contamination. Although borehole water demonstrated relatively improved quality, the presence of elevated iron, aluminium, and trace toxic metals indicates that it is not completely protected from contamination. Non-carcinogenic health risk assessment revealed that children are more vulnerable than adults, with cumulative exposure posing potential long-term health concerns, particularly for users of open well water.

The study confirms that open well water poses a greater toxicological risk than borehole water in the study area. Strengthening groundwater source protection, improving well construction and siting, routine water quality monitoring, and promoting appropriate household-level treatment options are essential to reduce exposure risks and safeguard public health in Ibotirem Town and similar coastal communities of the Niger Delta.

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