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Assessment of Drinking Water Quality Using Metal Index, Degree of Contamination and Hazard Indices on Ground Water Sources in an Agricultural Tropical Environment

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Abstract

The study conducted in the dry and rainy seasons of 2019 assessed the levels of metals in groundwater sampled from boreholes and dug wells in Ikwo, southeastern Nigeria. Nine water samples were analysed for calcium, iron, zinc, copper, manganese and aluminium using Atomic Absorption Spectrophotometer (AAS). Analysis showed higher metal concentrations in the rainy season, except for manganese whose concentrations were higher in the dry season. The levels of the metals exceeded permissible limits in both seasons except for calcium. The metal indices were not greater than 2, while all degrees of contamination was less than 1. This collaborative classification of both metal index and degrees of contamination suggests that the water samples were safe to drink. The health risks assessed by Hazard Indices (HI) were classified into low and medium (≥ 0.1 to < 4) levels of chronic risks. The HI values were evaluated for both children and adults. The HI values were predominantly medium for children and low for adults. All indices for water quality evaluation agree that groundwater in the study area is of minimal contamination hence, no immediate threat to health. Therefore to ensure quality water supply, sustainable monitoring of water quality is recommended in the study area.

Keywords: Degree of Contamination, Groundwater, Health Risk Assessment, Ikwo, Metals, Metal Index, Water Quality

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1. Introduction

Groundwater is the safest source of drinking water for a larger portion of communities around the world. The importance of water to humans, agriculture and industry cannot be over-emphasized. It is man's number one need for the sustenance of physiological and economic activities[1-3]. There is greater demand for safe drinking water now than there was in the last decade. This is due to an increase in industrialization, increased population growth, and wastewater management among others[4-9]. These factors are critical in providing safe and affordable drinking water, and they have a direct impact on community well-being[10-13]. However, the increase in population in urban and semi-urban settlements is a major challenge to the authority's ability to keep a constant and sufficient supply of safe water through good management of water resources[14,15]. The provision of safe drinking water is greatly challenged by limited finances and poor infrastructure in developing countries in Asia and Africa[16]. This challenge has driven communities to consume water directly from dug wells, streams, boreholes, rainwater and other natural waters without adequate prior treatment[17-19]. For example, it is estimated that approximately two-thirds of the Chinese population gets their water primarily from groundwater[20]. Prolonged exploitation of groundwater affects its availability and also affects its quality[21]. This suggests that the challenge of accessing safe drinking water is greater for rural dwellers.

Local authorities and non-governmental organisations are giving much attention to ensuring the supply of safe drinking water to all citizens, including those in rural settlements, but this is still a huge burden for developing countries. For instance, it is reported that there was a decline in accessibility to safe potable water from 1900–2015 during which there was a reduction from 2.6 billion people to 663 million who could access safe potable water. Sub-Saharan Africa was the most affected region[22-25]. The inability of the local authorities to maintain a safe water supply with large population growth is a challenge due to the high cost of travelling to and the location of piped water in rural areas. The poor sanitation in rural areas, occasioned by poor sewage systems and open defecation further increases water pollution in sub-Saharan Africa[23]. Groundwater contamination is a major environmental and health concern stemming from the nature of contaminants found in groundwater. The contaminants are introduced anthropogenically through the exploitation of groundwater resources or discharge of waste from industries or runoffs from farms or refuse dumps[26-29] or through natural processes like the weathering of geological formations and soils[30]. Human health is associated with environmental and groundwater contamination. This is widely observed in most developing communities[31]. The quality of groundwater as a source of potable drinking water is rapidly diminishing due to increased anthropogenic activities and increasing ingestion of contaminated water[3,32,33]. To ensure safe water for humans, information on contaminants obtained through monitoring is necessary. This will ascertain the extent of contamination and its associated human risk. Human risk assessment of water matches the concentration of contaminants with quality standards and health risk benchmarks[27,28,34]. Environmental monitoring of groundwater employs methodologies like the pollution index, carcinogenic and non-carcinogenic risk analysis, contamination degree, and metal indexes[6,28,35,36].

Ikwo Community is an agrarian community in the southeastern part of Nigeria with a fast-growing population. Its soil is characterised by a strong accumulation of heavy metals and the leaching of metals into the environment may set the stage for groundwater contamination[37]. Groundwater is the major source of drinking water in Ikwo. Ikwo communities experience acute water scarcity in the dry season as rainwater is seasonal. This seasonal scarcity is controlled by soil texture, geology, stream flow and rainfall level[37]. The volume of water at any season renders pollutants like metals of great concern and long-term exposure to contaminated water poses high health risks. Various researchers have agreed that securing safe drinking water quality is important for safeguarding human health[37-42]. There is no evaluation to ascertain the extent of contamination by metals and their health risk in the communities. Therefore groundwater quality in the communities is important in ascertaining the suitability of drinking water. The research aims to evaluate the metal contamination and human health risks through the following objectives: to determine the concentration of metals (Ca, Fe, Cu, Zn, Al and Mn); to evaluate the degree of metal contamination of groundwater in the area using an index approach, to assess health risk by calculating daily dose intake, hazard quotient and hazard index. These analyses will be carried out in dry and rainy seasons to determine seasons with a higher pollution index and the corresponding health risk[43-45]. The outcome of this work is expected to establish a preliminary baseline for effective monitoring of groundwater in the area from which information shall be a veritable tool for effective drinking water management for residents in the area.

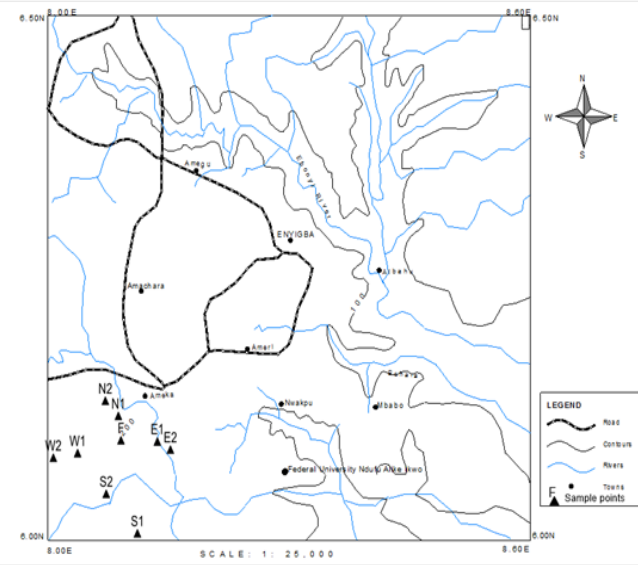


Figure 1. Map showing sample sites in Ikwo and environs.

2. Materials and Methods

2.1 Study Area

The study area (Figure 1) is located within Ikwo and its environs. The study area is drained by the Ebonyi River, with its numerous tributaries forming a dendritic pattern. Prominent towns within the study area include Enyigba, Ameka, Ameri and Amegu. Geologically, the area is composed of shales from the Asu River Group of the Albian age. The Shales serve as host rocks to the lead-zinc ores within the study area. The sediments of the Asu River are low-yielding aquifers that provide only small pumped water supplies except where they may be fractured, sheared or weathered[46]. There are two seasons experienced in this area: the dry season is between November and April, while the wet season is between May and October. The prevailing wind in the dry season is the harmattan wind, while the northward wind of the inter-tropical zone ushers in the monsoon rainfall. With an average annual rainfall of 1800 mm, the northward wind keeps the temperature below 28°C[47]. The average elevation of the study area is generally less than 250m. The population of Ikwo is sparsely dense and mostly composed of farmers and petty traders.

2.2 Sampling and Laboratory Analysis

The predominant sources of drinking water in the Ikwo community are boreholes and dug wells, which extract water from aquifers. The topography of Ikwo is fairly uniform with uniform geological parent material spreading beneath the surface[37]; therefore, nine drinking water samples were used to achieve the aim of this study. The sampling was carried out in two seasons: in March 2019, during the dry season corresponding to the low water period and in October 2019, during the rainy season corresponding to the high water period. A total of nine water samples per season were collected using 1L sterilized polyethylene bottles. These samples represented nine sampling sites (north (N), south (S), east (E), west (W) and central area (F)) as shown in Table 1 and were intended for metal analyses. The sample bottles were washed and soaked in 1:1 dilute HCl for 24 hrs, and rinsed with distilled water. Before collecting the water samples, the sterilised bottles were rinsed with source water. Water samples were acidified with 1% HNO_3 and preserved for onward analysis. The samples were digested and concentrated and metal analysis was carried out using Atomic Absorption Spectrophotometry (model 200S). The metals measured were: iron (Fe), manganese (Mn), copper (Cu), calcium (Ca), aluminium (Al), and zinc (Zn). All analyses in the laboratory were carried out within 48 hrs of sample collection. The data from the analysis of water samples in the dry season were compared with those in the rainy season.

2.3 Quality Control of Results

Procedural blanks were used to correct for background absorption and values of measured heavy metals were expressed in mg/L[48]. The heavy metals were evaluated by comparing mean levels obtained in the dry and rainy seasons.

2.4 Metal Contamination Assessment

The metal contamination of the water samples was evaluated using the Metal Index (MI), Contamination factor (Cf) and degree of contamination (Cd). These describe the limits and extent of pollution of water by metals[6,35,49-51].

2.4.1 Metal Index (MI)

The metal index has been used to describe the quality of drinking water[25]. This index accounts for the possible additive effect of metals on human health. Its expression was first proposed by Caeiro, *et al.*,[52] and it is calculated thus;

$$MI = Ci/m \quad (1)$$

Where m = permissible concentration. The m values used in this study were adopted from Mukanyandwi, *et al*[6]. Ci is metal concentration. When a metal index value exceeds unity, it signifies a threshold of warning[53] and this was

Table 1. Sample coordinates in the Ikwo study area

Sampling spot	Latitude	Longitude	Elevation (ft)
N1	6⁰09'40.07"N	8⁰07'48.67"E	142
N2	6⁰10'25.43"N	8⁰06'55.63"E	168
S1	6⁰05'26.61"N	8⁰09'06.03"E	131
S2	6⁰05'36.95"N	8⁰06'56.37"E	172
E1	6⁰08'18.78"N	8⁰10'30.88"E	95
E2	6⁰07'53.85"N	8⁰11'23.95"E	102
W1	6⁰07'42.88"N	8⁰04'57.10"E	182
W2	6⁰07'31.17"N	8⁰03'17.88"E	242
F	6⁰08'27.56"N	8⁰07'58.25"E	126

Table 2. Classification of Contamination degree (Cd) and Metal Index (MI)

Cd	Contamination level	Class	MI	Contamination level	Class
<1	Low	1	<0.3	Very pure	1
1<Cd	moderate	2	0.3-1.0	Pure	2
Cd>3	High	3	1.0-2.0	Slightly	3
			2.0-4.0	Moderately	4
			4.0-6.0	Strongly	5
			>6.0	Seriously	6

applied to the metals analysed in this study to know which metals had more contamination impact on drinking water.

2.4.2 Degree of Contamination (Cd) and Contamination Factor (Cf)

The degree of contamination sums all parameters whose effect is regarded as harmful[35]. The parameters whose effects render drinking water polluted or safe are referred to as Cf. Hakanson[54] classified Cf into four categories, which include: Class 1 (Cf < 1); Class 2 (1 ≤ Cf < 3); Class 3 (3 ≤ Cf < 6); and Class 4 (Cf ≥ 6). The degree of contamination is the sum of Cfs in the water samples. In this study Cd was calculated as follows:

$$Cd = \sum_{i=1}^{n} (Cf) \qquad 2$$

Where Cf = (C_{Ai} / m) – 1; C_{Ai} = measured concentration of the metal, m = permissible value of the metal whose values are just as m used for MI.

The classification of Cd and MI in drinking water as proposed by Hakanson[54] is shown in Table 2.

2.4.3 Health Risk Assessment

The health risk evaluation was done by calculating the daily exposure dose (mg kg^{-}day^{-}) using guidelines published by the US-EPA[55]. The daily exposure dose was determined for both adults and children. The daily exposure dose evaluates the risks posed by ingesting a single metal[28]. The daily exposure was used in evaluating the Hazard Quotients (HQ) and Hazard Indices (HI) of individual water samples.

The daily exposure dose is the chronic daily intake of the metals in the water samples and it is the ratio of the products of the analytical concentration of the metal under investigation, C (mg /L); the water ingestion rate W (1 litre for children and 2 litres for adults); the Exposure Frequency (EF) and Duration of Exposure (ED) to the product of body weight of the consumer (B); and the average exposure time (T) for both children (2190 days) and adults (25,550 days)[27].

$$\text{Daily exposure dose (mg kg}^{-}\text{ day}^{-}\text{)} = \frac{C \times W \times EF \times ED}{B \times T} \quad 3$$

HQ evaluated the health risk of ingesting a single metal for a given duration. HQ was calculated using reference doses (Rm) of specific metals (Fe, Zn, Cu and Mn).

$$HQ = \frac{Daily\ exposure\ dose}{Rm} \quad 4$$

Where Rm values were: (0.7) Fe, (0.3) Zn, (0.04) Cu and (0.046) Mn[27,28]. HI was used to classify the carcinogenic risk associated with the water samples. Based on the US-EPA[55] classification, HI > 1 implies that there is a health risk in ingesting the elements at the prevailing analytical concentrations, while the reverse (HI < 1) shows little or no health risk involved in drinking the water sample. Mgbenuand Egbueri[27] and Bortey- Sam, *et al.,*[56] classified the health risk based on HI as negligible (< 0.1), low risk (≥ 0.1 <

Table 3. Mean metal concentrations (mg/L) of sites in both the dry and rainy seasons

		Site										
Element	**Season**	**N1**	**N2**	**S1**	**S2**	**E1**	**E2**	**W1**	**W2**	**F**	**Metal X**	**m**
Ca	Ds	38.4	45.00	66.7	32.1	86.54	37.2	32.1	60.3	26.3	47.18	80
	Rs	68.7	75.2	80.9	63.8	102.2	54.7	32.2	37.8	77.7	65.91	
Fe	Ds	0.31	0.31	0.77	0.86	0.09	0.2	1.01	0.41	0.49	0.49	0.3
	Rs	0.66	0.61	1.24	0.11	0.41	0.08	0.65	0.18	0.71	0.52	
Mn	Ds	0.78	0.54	0.08	0.31	0.49	0.48	0.09	0.40	0.19	0.37	0.1
	Rs	0.24	0.32	0.01	0.46	0.26	0.24	0.16	0.16	0.38	0.25	
Cu	Ds	0.58	0.71	1.38	0.88	0.64	1.31	1.08	0.09	0.003	0.74	1
	Rs	0.80	1.18	1.44	1.02	0.86	1.76	2.02	0.65	0.92	1.18	
Al	Ds	0.19	0.11	0.66	1.06	0.71	0.66	0.008	0.04	0.006	0.38	0.2
	Rs	0.04	0.15	0.26	1.00	1.08	1.10	0.06	0.19	0.32	0.47	
Zn	Ds	0.93	0.78	1.00	0.63	0.55	0.33	0.14	1.00	0.46	0.65	0.3
	Rs	1.13	1.08	0.70	0.78	0.96	0.73	0.04	1.01	0.88	0.81	
Site X	Ds	6.87	7.91	11.77	5.97	14.84	6.70	5.74	10.37	4.57		
	Rs	11.93	13.09	14.09	11.20	17.63	9.77	5.86	6.67	13.49		

X = mean, Ds = Dry season, Rs = Rainy season, m = permissible limits

Table 4. Seasonal variation of contamination factors and metal index of metals in drinking water

	Rainy season			Dry Season		
Element	**Cf**	**MI**		**Cf**	**MI**	
Ca	-0.18	0.82		-0.41	0.59	
Fe	0.73	1.73	threshold of warning	0.63	1.63	threshold of warning
Mn	1.5	2.5	threshold of warning	2.7	3.7	threshold of warning
Cu	0.18	1.18	threshold of warning	-0.26	0.74	
Al	1.35	2.35	threshold of warning	0.9	1.9	threshold of warning
Zn	1.7	2.7	threshold of warning	1.17	2.16	threshold of warning

Cf = Contamination Factor, MI = Metal index, MI > 1 = threshold of warning53

Table 5. Classification of degree of contamination and metal index of water samples from individual sites in Ikwo

Sample site	MI Rs	classification	Cd Rs	classification	MI Ds	classification	Cd Ds	classification
1	0.85	Pure (class 2)	-0.15	Low (class 1)	0.49	Pure (class2)	-0.51	Low(class 1)
2	0.93	Pure (class 2)	-0.07	Low (class 1)	0.56	Pure (class 2)	-0.44	Low(class 1)
3	0.99	Pure (class 2)	-0.01	Low (class 1)	0.83	Pure (class 2)	-0.17	Low(class 1)
4	0.79	Pure (class 2)	-0.21	Low(class 1)	0.42	Pure (class 2)	-0.58	Low(class 1)
5	1.25	Slightly affected (class 3)	0.25	Low(class 1)	1.05	Slightly affected (class 3)	0.05	Low(class 1)
6	0.69	Pure (class 2)	-0.31	Low(class 1)	0.48	Pure (class 2)	-0.53	Low(class 1)
7	0.42	Pure (class 2)	-1.42	Low(class 1)	0.41	Pure (class 2)	-0.59	Low(class 1)
8	0.47	Pure (class 2)	-0.53	Low(class 1)	0.78	Pure (class 2)	-0.26	Low(class 1)
9	0.96	Pure (class 2)	-0.04	Low(class 1)	0.32	Pure (class 2)	-0.68	Low(class 1)

Ds = dry season, Rs = Rainy season, Cd = degree of contamination, Cd < 1 = low, 1< Cd = moderate, Cd > 3 = High contamination

Table 6. Results of hazard indices of the water samples

Sample area	season	HI (Adult)	Chronic risk level	HI (children)	Chronic risk level
N1	DS	1.000	Low	2.3333	Medium
	RS	0.8550	Low	1.9951	Medium
N2	DS	0.9295	Low	2.1690	Medium
	RS	1.1694	Medium	2.7290	medium
S1	DS	1.1621	Medium	2.6360	medium
	RS	1.1521	Medium	2.5900	medium
S2	DS	0.9162	Low	2.1380	medium
	RS	1.0931	Medium	2.5500	medium
E1	DS	0.8173	Low	1.9080	medium
	RS	0.8839	Low	2.0630	medium
E2	DS	1.2734	Medium	2.9710	medium
	RS	1.4790	Medium	3.4510	medium
W1	DS	0.8819	Low	2.0580	medium
	RS	1.5726	Medium	3.6690	medium
W2	DS	0.4247	Low	0.9910	low
	RS	0.6672	Low	1.5570	medium
F	DS	0.1840	Low	0.4290	low
	RS	1.0060	Low	2.3470	medium

1), medium risk (≥ 1 < 4) and high risk (≥ 4). HI is therefore the summation of HQ values of metals in a water sample.

3. Results

The mean metal concentrations of water samples in the dry and rainy seasons are summarised in Table 3.

The results showed a gradual increase in metal concentration in the rainy season as compared to the dry season. The abundance of the metals did not follow any clear pattern. However, calcium showed the highest abundance in all sample sites and both the dry and rainy seasons. For convenience, the average metal concentration (Metal X) showed a higher metal effect in the rainy season compared to the dry season. Furthermore, the metal concentrations were greater than m values except for Ca and Cu during Ds, i.e., metal X < 80 and X < 1 (Table 3). The mean values of the metals were used to compute the Cf of individual metals and the metal index in the water samples for the dry and rainy seasons, as shown in Table 4.

The Cf of all the metals reveals that they were of low effect in contaminating the water and therefore fell within categories 1 and 2. Table 5 shows the Cd of water from the nine sample sites both in the dry and rainy seasons. The Cd classified drinking water quality into 3 classes as illustrated in Table 2. Based on the classification shown in Table 2, the Cd values of all the water sampled in both seasons are classified in class 1 and characterised as low-contaminated water. The health risk assessment evaluated by hazard indices is summarised in Table 6. The chronic risk levels of adults and children ranged from low to medium levels in both seasons. Although all chronic risk levels are acceptable, children have higher health risks from drinking water from the study area.

4. Discussion

4.1 Assessment of Metal Concentrations in Water Samples

Table 3 shows higher concentrations of metals in the rainy season compared to the dry season. The results showed varying concentrations of the metals, with calcium recording the highest level (102.2 mg/L, and 86.54 mg/L) in both the rainy and dry seasons, respectively. Calcium showed the highest values in both seasons in E1. E1 was the only site whose calcium values were higher than the permissible value, i.e., m. The highest concentration of Fe (1.24 mg/L) was recorded in the rainy season in S1. The highest value of Fe in the dry season was recorded in W1 (1.01 mg/L). The abundance of Fe is probably from soil geochemistry and the abundance of metal in the soil is occasioned by high geoaccumulation[37]. Manganese (Mn) showed the highest concentration (0.78mg/L) in the dry season in N1. Generally, Mn showed a decrease in concentration in the rainy season across sample sites except in S2, W1 and F. The concentrations of Mn in this study (Table 3) exceeded permissible limits (m). The concentrations of Mn are probably from rocks and aquifers since Mn occurs in rocks and soils and are widespread in the environment[57]. The Fe and Mn concentrations found in this study were higher than those found in Amike-Aba, Ebonyi State (unpublished). Copper (Cu) showed consistently elevated levels in the rainy season when compared to Cu values in the dry season. The highest Cu values were recorded in S1 (1.44 mg/L, 1.38 mg/L) for both the rainy and dry seasons. The highest Al value (1.10 mg/L) was recorded in E2 in the rainy season, while its highest value in the dry season (1.06 mg/L) was in S2. The variation in concentrations was not wide. Thus, either meteorologic or geologic factors were responsible for the concentration of Al at the selected sites. Complexes of aluminium with organic acids reduce aluminium toxicity to organisms. Iron and manganese exhibit similar chemistry, which makes them bioavailable in aquatic biota. Their presence in water increases water acidity[49]. Zinc had its highest (1.13 mg/L) values recorded in N1 in the rainy season and 1.00 mg/L in the dry season in S1 and W2. Generally, elevated levels of Zn were observed in the rainy season compared to the dry season. Table 3 showed an average of metal concentrations across sample sites (metal X) to be generally higher in the rainy season, except for Mn whose average was greater in the dry season. This may be influenced by a geologic factor and not a meteorological factor. Table 3 also showed that all metals regardless of the season, were far greater than m, except for Ca. The relative abundance of tested metals was in the following order: Ca > Cu > Zn > Fe > Al > Mn. Ikwo is located in an area mineralized with galena, sphalerite, arsenopyrite, marcasite and other associated minerals and weathering of these minerals can yield these metals in aquifers[46,58]. The high concentration of these metals (Ca, Fe, Zn, Cu, Mn and Al) in groundwater samples in Ikwo is most likely due to the aquifer rock chemistry and little or no input from the impact of mining or agriculture. Fertilizers contain metals and despite a heavy application to farms in the area, the release of the observed concentration of the metals into the groundwater did not cause outrageous metal contamination, as shown in Table 4. The metal concentration

may be attributed to the weathering of underlying parent rocks.

4.2 Contamination Indices of Water Samples From Sites

This study is the pioneer in assessing seasonal variation in heavy metals of drinking water in Ikwo. The extent of contamination of water by the metals is further described by the metal index and degree of contamination in Table 5. The highest metal index in the rainy season was 1.25 and 1.05 in the dry season. Based on the classification of MI for the quality of drinking water, all sites, except W1 fell into class 2 (Tables 2 and 5). Water obtained from E1 is classified as slightly affected (Table 5). All the water samples were pure and safe to drink. There was a consistent increase in MI across all sites in the rainy season, with the highest value observed in E1 (1.25) and water from E1 classified as 2 (Table 5). The MI results for Zn and Cu in this study were compared with those in the neighbouring Enyigba community bordering Ikwo. The metal index was also classified in class 1[59], but no mention was made of the season in which the study was conducted. Higher MI values indicate the greater impact of the metals on contaminating the water sample under investigation. The highest class of drinking water by MI is 6 and this is when water is seriously contaminated[53].

The range of degree of contamination (Cd) was (-0.53 to 0.25). During the rainy season, the highest value of Cd (0.25) was observed in E2, while the lowest value (-0.53) was in W2. In the dry season, the highest value of Cd recorded (0.05) was in E1 and the lowest, (-0.68) was in F. Based on the classification of degree of contamination, all the water sampled in both seasons is classified as low contaminated water (Table 2). The results of this study indicated that the degree of contamination of the environment was due to natural processes rather than anthropogenic activities. The findings from the different sources of drinking water, irrespective of the season, show that the metals in them were higher than permissible limits (m), but they have a low effect on the contamination of the water accessed for drinking in Ikwo.

4.3 Health Risk Assessment

The health risk posed by ingesting metals in the groundwater samples is shown by the HI of the elements analysed in the samples that represent the nine areas of Ikwo and environs (Table 6). The HI values ranged from ≥ 0.1 to < 4 and are thus classified as low and medium levels of chronic health risk. Both categories are fit for drinking. However, the majority of water samples were of medium health risk in the rainy season. Although suitable for drinking, it still suggests a greater threat to health. There was a higher risk for children. The medium risk levels were a result of the abundance of Cu. Consuming water with elevated levels of metals poses health risks like brain damage, kidney failure, nervous system destruction, etc[10]. Therefore, simple treatment of water like boiling or using resins is required before drinking.

5. Conclusion

This pioneering study of seasonal monitoring of drinking water quality used the metal index and degree of contamination of water sourced from boreholes and dug wells in Ikwo rural communities to monitor water quality in the dry and rainy seasons. The results indicated that all metals analysed in this study (Ca, Fe, Zn, Mn, Al and Cu) exceeded WHO (m) for drinking water, which is a consequence of high geo-accumulation of the metals in the soil; however, their indices suggest that their contribution to water contamination is low. Thus, based on collaborative information given by the metal index and degree of contamination, the water samples are safe drinking water samples. The results revealed higher metal concentrations for rainy-season reasons but posed no immediate risk to human health. The levels of metals in Ikwo water are influenced mainly by either geological or meteorological factors and not anthropogenically. This study recommends sustainable monitoring of water quality to ensure a good water supply to Ikwo and its environs.

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