IJBPAS, July, 2022, 11(7): 2914-2933

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

COMMUNITY HEALTHRISK ASSESSMENT OF DRINKING WATER: A CASE STUDY OF HAND-DUG WELLS IN ABAKALIKI, SOUTHEASTERN NIGERIA

***UWA, C.U., OLAGUNJU, T. E.AND BABALOLA, S.O.**

Department of Biology/Microbiology/Biotechnology, Alex Ekwueme Federal University, Ndufu-Alike Ikwo, Ebonyi State, Nigeria

***Corresponding Author: Dr. Uwa CU**

Received 4th Sept. 2021; Revised 8th Oct. 2021; Accepted 26th Nov. 2021; Available online 1st July. 2022

https://doi.org/10.31032/IJBPAS/2021/11.7.6191

ABSTRACT

This research assessed the physico-chemical parameters (pH, EC, Cl^-, $NO3^-$, $SO4^{2-}$, TS, TDS, TSS and TH) and levels of Fe, Ni, Cd, Hg, Mn, Pb, Cu, Zn and F in hand-dug wells in ten localities in Abakaliki, Southeastern Nigeria. CI and human health riskwere assessed using appropriate models.pH values were within a range of 4.50 - 7.67 with most of the water samples were slightly acidic.EC, TS, TDS and TSS hadranges of 198µs/cm - 978µs/cm, 30mg/l - 50mg/l, 10mg/l - 50mg/l and 10mg/l to 40mg/l respectively.Samples from W2, W3, W4, W5, W6, W7, W9 and W10 had high levels of one or more of Cl^-, NO_3^- and SO_4^{2-}above the recommended limits. Meanwhile, W5 and W10 had high TH of 133.00mg/l and 104.00mg/l respectively. Analysis of Fe, Ni, Cd, Hg, Mn, Pb, Cu, Zn and F showed their ranges to be 0.09mg/l – 0.29mg/l, 0.11mg/l – 3.57mg/l, 0.02mg/l – 0.49mg/l, 0.42mg/l – 0.92mg/l, 0.01mg/l – 0.05mg/l, 0.04mg/l – 0.23mg/l, 0.10 – 1.49mg/l, 0.01 – 0.15mg/l and 0.44mg/l – 0.57mg/l respectively. Ni had the highest concentration in all samples analysed with the highest value (3.57mg/l) in sample from W10. Correlation analysis showed that positive, negative and no correlations accounted for 52.78%, 8.33% and 38.89%.of elemental association respectively.No well had contamination due to Fe, Mn, Cu, Zn and F but, all of them had between 80% and 100% contamination by Cd, Hg, Ni and Pb. HQ values was > 1 for all analysed trace elements except for Ni in W6, Cd in W9, Pb in W7. The range of HI in children was 120.78 – 391.30 and 61.57 – 121.26 in adults. CRI for Pb was not within the acceptable range in all the wells. Children were at higher non-carcinogenic and carcinogenic health risks than adults. This research concluded that none of the hand-dug well is fit as source of drinking water.

Keywords: Health risk, trace elements, drinking water, hand-dug well, Abakaliki

1. INTRODUCTION

The importance of water to human health and existence cannot be overemphasized. The quality of drinking water is an essential determinant of health **(WHO, 2010)**. Drinking water quality management has been a pillar for the prevention and control of waterborne diseases. **Cheebroiugh (2006)** reported that 80% of diseases in developing countries are due to lack of portable water. **Oluwasanya (2009)** attributed inaccessibility to safe drinking water in Nigeria to poor socio-economic development, growing industrialization, poor planning, insufficient allocation of fund in the water sector and haphazard implementation amongst others. Furthermore, 52% of Nigeria population was reported to lack access to potable water **(Oluwasanya, 2009)**.

Groundwater is well thought-out to be vital natural and freshwater resource on earth and it is used for drinking, domestic and irrigation purposes. Groundwater is a primary source of water to non-riverine population, but it is threatened by anthropogenic contaminants particularly in developing countries like Nigeriawhere input oftoxic contaminants to the environment is poorly restricted. Meanwhile, exploitation of groundwater for drinking through the construction of hand-dug wells is a popular practice in Nigeria **(Ayantoboet *al*., 2012)**. Unfortunately, the development of groundwater has been undertaken by developers that do not have the requisite scientific and technological know-how to produce water that are less prone to contamination during exploitation.

Water contaminationis a global public health concern whichmakes people to beat risk of diarrhoeal and other waterborne illnesses as well as chemical intoxication **(Okonkoet *al.*, 2009)**. In the last few decades, risk of exposure to toxic element contaminants in drinking water has increased due to proliferation of anthropogenic activities that are unsustainably carried out **(Rezaeli*et al*., 2019)**. Although some metals such as Cu and Zn amongst others are necessary for normal metabolic functioning in living organisms but at high concentrations, such metals as well as others such as Pb, As, Cd etc. that are non-essential are toxic to physiological systems even at low concentrations.

Residents of Abakaliki, rely heavily on hand-dug well for drinking and other domestic uses. Those that have boreholes use well water as complimentary water source.Therefore, this research aimed to determine the physico-chemical parameters and levels of toxic elements in hand-dug wells used for drinking in localities within the urban municipal of Abakaliki, southestern Nigeria. In addition, the study elucidated the contamination index and assessed the health risk associated with toxic elements present in the water samples from the hand-dug wells.

2.0 MATERIALS AND METHODS

2.1 Study area

Abakaliki is the state capital of Ebonyi State, Southeastern Nigeria within latitude 6.32^{0}N and longitude 8.12^{0}E **(Figure 1)**. It is in the tropical geographical zone and according to the Koppen-Geiger climate classification, the prevailing climate of Abakaiki is Aw with an average temperature of 27.7^{0}C. The capital city has an elevation of 177m above the sea level, generally characterized by flat topography.Abakaliki is characterized by two climatic seasons; the raining season (April – October) and dry season (November – March) with mean annual rainfall of 1918mm/yr. There is usually a decline in rainfall in Augusts, regarded as “August break”.In 2015, Abakaliki was estimated to have population of 438,700 in 2015 **(Population City, 2015)**. Groundwater sources which are known to be shallow in depth of about 30m to 40m constitute primary water sources for inhabitants **(Aghamelu*et al*., 2011)**. Abakaliki is located at the intersections of roads from three other cities; Enugu, Afikpo and Ogoja.

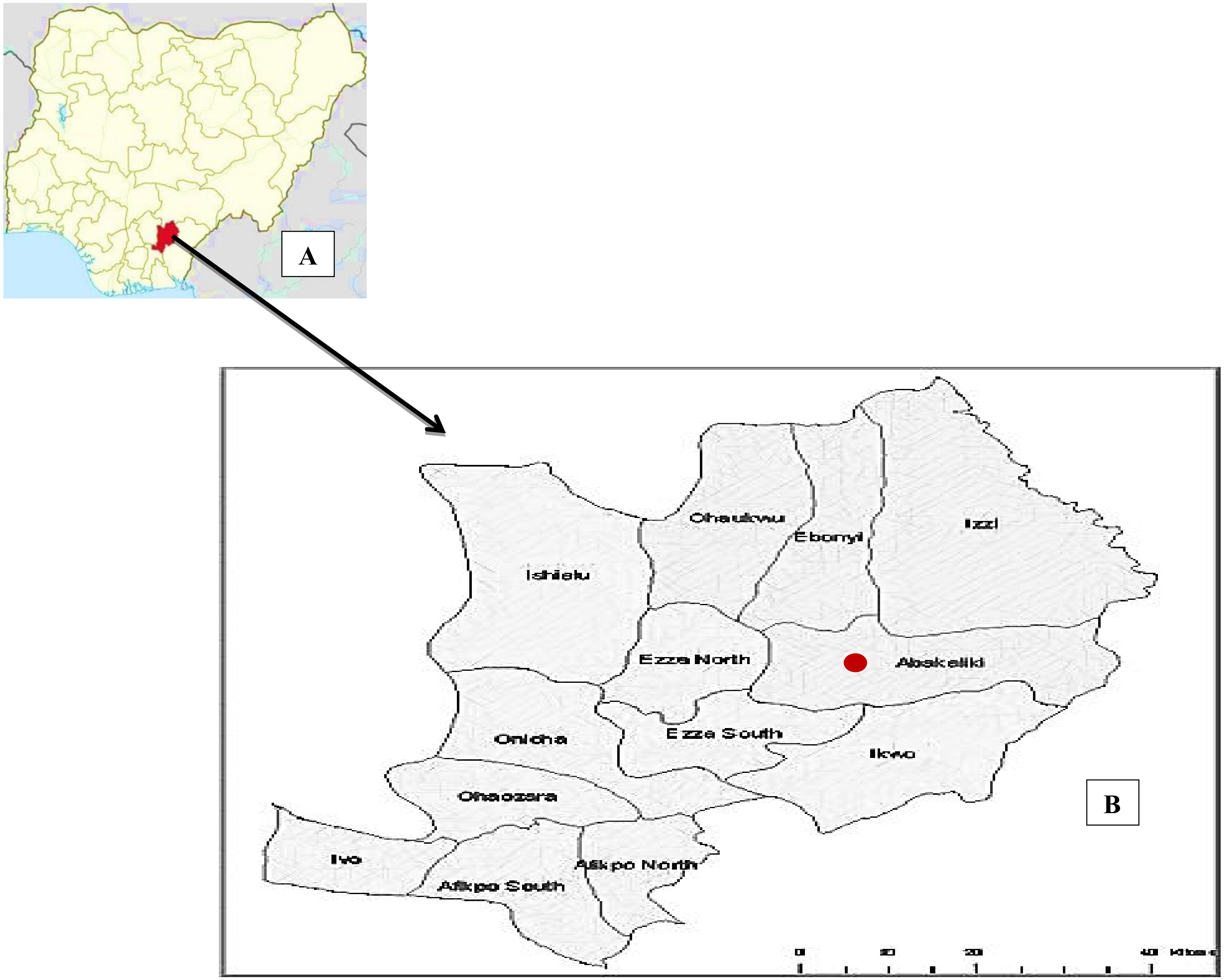

Figure 1: Map of Nigeria showing Ebonyi State (A) and map of Ebonyi State showing Abakaliki (B)

2.2 Sampling, physico-chemical and trace element analyses

Samples were collected on 25th March, 2018from wells in ten localities within the urban municipal of Abakaliki and these localities include: Ugwuachara (W1), Mile 50 (W2), Kpirikpiri (W3), Presco (W4), Spera-in-Deo (W5), Rice Mill (W6), Iyiokwu (W7), CAS (W8), New Layout (W9) and Hilltop (W10). Water samples were collected from hand-dug wells into prewashed and deionized plastic bottles before analysis. Physicochemical analyses including pH, electrical conductivity (EC), chloride (Cl^-), nitrate ($NO3^-$), sulphate ($SO4^{2-}$), total solids (TS), total dissolved solids (TDS), total suspended solid (TSS) and total hardness were done according to APHA (1998). Analysis of iron (Fe), nickel (Ni), cadmium (Cd), mercury (Hg), manganese (Mn), lead (Pb), copper (Cu) and zinc (Zn) was done according to standard procedures and quantified using atomic absorption spectrophotometry (AAS).Fluorine (F) levels in the samples werequantified according to APHA (1995).

2.3 Contamination index (CI)

Contamination index (CI) was calculated as the ratio of concentration of metal in water sample to maximum allowable concentration of the metal (eqn. 1) using NSDWQ (2010) standard.

$$CI = \frac{Cw}{MAC} \ldots\ldots\ldots\ldots\ldots..1$$

CI = contamination index, Cw = concentration of trace elements in water samples and MAC = maximum allowable concentration. Contamination index is classified as; > 5 (contaminated); $1 \leq CI \leq 5$ (slightly contaminated) and; < 1 (not contaminated)

2.4 Human health risk assessment

USEPA risk models (eqn. 2 to 5) were employed to assess human health risks (non-carcinogenic and carcinogenic) both for children and adults via oral route due to exposure to Fe, Ni, Cd, Hg, Mn, Pb, Cu and Zn in the well water samples.

2.4.1 Non-carcinogenic health risk

Non-carcinogenic health risk was estimated by calculating hazard quotient (HQ) and hazard index (HI).

$$HQ = \frac{CDI}{RFD} \ldots\ldots\ldots\ldots\ldots\ldots..2$$

$$HI = \sum HQ \ldots\ldots\ldots\ldots\ldots\ldots3$$

Where HQ = hazard quotient, CDI = chronic daily intake, RFD = reference dose and HI = hazard index.

Oral reference doses (mg/kg/day) for Fe, Ni, Cd, Hg, Mn, Pb, Cu, and Zn are: 0.3, 0.02, 0.0005, 0.003, 0.02, 0.0014, 0.04 and 0.3 respectively.

$$CDI = \frac{Cw \times IR \times EF \times ED}{BW \times AT} \ldots\ldots\ldots\ldots\ldots\ldots 4$$

Cw is the concentration of trace element; IR is the ingestion rate; EF is the exposure frequency; ED is the exposure duration; BW is the body weight; AT is the average time.

If HQ > 1; trace element would elicit non-carcinogenic health effect and HI > 1 revealed that the total trace elementsin a sample would jointly cause adverse non-carcinogenic health effect.

IR = 1L/day for child and 2.2L/day for adult

EF = 365 day/year

ED = 6 years for child and 45 years for adult

BW = 15 kg for child and 65 kg for adult

AT = 2190 days for child and 16425 days for adult

2.4.2 Carcinogenic health risk

$$CRI = CDI \times SF \ldots\ldots\ldots\ldots\ldots\ldots 5$$

CRI= Cancer risk index, CDI= chronic daily intake and SF = slope factor for a trace element. Currently, oral SF is available for only Pb among all the trace elements analysed. The oral SF for Pb is 8.5 E-3. Hence, carcinogenic risk was calculated for only Pb through oral route. Acceptable value of cancer risk is $1 \times 10^{-6} \leq CRI \leq 1 \times 10^{-4}$.

2.5 Statistical analysis

Statistical analysis of the data such as range, mean and correlation analysis were performed using Excel 2010 (Microsoft Office) and SPSS (ver. 20).

3.0 RESULTS

3.1 Physico-chemical and trace element analyses

The results of physico-chemical analysis and analysis of trace elements present in water samples from hand-dug wells in Abakaliki are presented in **Table 1 and Figure 2** respectively. The temperature ranged from the lowest 28^0C of samples from Ugwuachara to the highest 31.5^0C of samples from Rice Mill localities with mean temperature of 30.2^0C in all samples which is within the NAFDAC, NSDWQ and WHO stipulated ambient temperature. The pH values were within a range of 4.50 and 7.67 with amean value of 6.20 in all samples. However, most of the water samples were slightly acidic being less than pH of 7.Water samples from Iyiokwuhadn-dug well had the highest acidity with pH of 4.50, while that of the Hill Top well was highly alkaline at pH of 7.67.

Electrical conductivity (EC) analysis of samples ranged from 198 to 978µs/cm with Ugwuachara well (W1) having the lowest conductivity while highest was recorded in samples from Kpirikpiri (W3). These values are within the recommended limits by NAFDAC, NSDWQ and WHO.

Total solids (TS) and total dissolved solids (TDS) analysed were within the acceptable limits with the former ranging from30mg/l to 50mg/l while the later was in a range of 10mg/l to 50mg/l. However, analysis of total suspended solids (TSS) revealed that water sample from Mile 50 (W2) had higher value (40mg/l) than the maximum limit of 30mg/l recommended by the WHO but other samples were within the recommended limit. Sample from Presco (W4) had the lowest TSS value of 10mg/l.

Chloride(Cl^-) analysis of all samples showed a mean of 65.38mg/l with a range of 24.82 to 122.12mg/l with the lowest value recorded in sample from Ugwuachara(W1) and the highest in samples from Kpirikpiri (W3).Cl^-level of samples of W3 was above the recommended limit by NAFDAC. The ranges of nitrate (NO_3^-) and sulphate (SO_4^{2-}) were 8.62 to 32.60mg/l and 36.31 to 71.46mg/l respectively. Samples from Mile 50 (W2), Presco (W4), Spera-in-Deo (W5), Rice Mill(W6), Iyiokwu (W7), New Layout(W9) and Hilltop (W10) which were of 22.10mg/l, 11.60mg/l, 16.20mg/l, 14.30mg/l, 18.20mg/l, 14.00mg/l and 32.60mg/l NO_3^-concentrations respectively were significantly higher than the recommended 10.00mg/l by NAFDAC and WHO.Levels of SO_4^{2-} in all samples were within the acceptable limit with the mean value of 54.34mg/l and the lowest and highest values recorded in W2 and W7 respectively.Total hardness (TH) had its lowest value in sample from W7 (28.80mg/l) and highest value in sample from W5 (133.00mg/l). Meanwhile, samples from W5 and W10 had values of 133.00mg/l and 104.00mg/l respectively which were higher that the NAFDAC maximum permissible limit of 100.00mg/l.

Analysis of Fe, Ni, Cd, Hg, Mn, Pb, Cu, Zn and F showed their ranges to be 0.09mg/l – 0.29mg/l, 0.11mg/l – 3.57mg/l, 0.02mg/l – 0.49mg/l, 0.42mg/l – 0.92mg/l, 0.01mg/l – 0.05mg/l, 0.04mg/l – 0.23mg/l, 0.10 – 1.49mg/l, 0.01 – 0.15mg/l and 0.44mg/l – 0.57mg/l respectively. Fe concentrations in all the samples were within the NAFDAC, NSDWQ and WHO regulatory limits. Conversely, all samples had higher concentration of Ni than the NSDWQ permissible limits. Also, Ni had the highest concentration in all samples analysed with the highest value (3.57mg/l) in sample from Hilltop. Cd and Hg had higher values in all samples than the NSDWQ limits.Mn was not detected in samples from W1, W3, W4, W5 and W8 but its highest concentration (0.05mg/l) in sample from W10was within the recommended limits. Levels of Pb in all the samples were higher than 0.01mg/l recommended limit by NAFDAC, NSDWQ and WHO. Cu, Zn and F concentrations in all samples from all the ten localities were within the regulatory limit except Cu (1.49mg/l) at W7.

3.2 Correlation Analysis

The result of Pearson correlation analysis at $p < 0.05$ is presented in table 2.Negative and positive correlations accounted for 52.78% and 8.33% of elemental association respectively while no correlation accounted for 38.89%. Positive correlation existed only between the following duos of trace elements; Ni-Zn, Cd-F, and Cu-Zn. Fe negatively correlated with Ni, Cd, Hg, Mn, Cu and Zn. No significant ($p < 0.05$) correlation existed between; Fe-Pb, Fe-F, Ni-Cd, Ni-Mn, Ni-Cu, Ni-F, Cd-Hg, Cd-Cu, Cd-Zn, Mn-Pb, Mn-Cu, Mn-Zn, Cu-F and Zn-F. Negative correlation occurred between the following elemental pairs; Fe-Ni, Fe-Cd, Fe-Hg, Fe-Mn, Fe-Cu, Fe-Zn, Ni-Hg, Ni-Pb, Cd-Mn, Cd-Pb, Hg-Mn, Hg-Pb, Hg-Cu, Hg-Zn, Hg-F, Mn-F, Pb-Cu, Pb-Zn and Pb-F.

3.3 Contamination index (CI) estimation

Contamination index (CI) estimated for Fe, Ni, Cd, Hg, Mn, Pb, Cu, Zn and F in water samples from the study area is presented in figure 3. None of the water samples from all the localities of the study area had contamination due to Fe, Mn, Cu, Zn and F. Meanwhile, all samples had metal contamination due to Cd and Hg. For Ni, 90% of the samples had contamination due to Ni while 10% was slightly contaminated.There were 80%, 10% and 10% of the samples contaminated, slight contaminated and not contaminated respectively by Pb.

Table 1: Physico-chemical analysis of sampled well water in the study area

Parameters	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	NAFDAC	NSDWQ	WHO
Temperature (^{o}C)	28.0	28.9	29.7	30.0	31.5	31.1	30.4	31.2	30.6	30.2	Ambient	Ambient	Ambient
pH	6.70	6.29	6.30	6.55	6.48	5.57	4.50	6.12	5.77	7.67	6.5-8.5	6.5-8.5	6.5-9.5
Electrical conductivity (EC) (µs/cm)	198	247	978	324	746	399	547	509	844	958	1000	100	1200
Total solids (TS) (mg/l)	30.00	50.00	80.00	40.00	30.00	30.00	40.00	40.00	40.00	50.00	500	500	500
Total dissolved solid (TDS) (mg/l)	10.00	10.00	50.00	30.00	10.00	10.00	20.00	20.00	20.00	20.00	NA	500	250
Total suspended solids (TSS) (mg/l)	20.00	40.00	30.00	10.00	20.00	20.00	20.00	20.00	20.00	30.00	NA	NA	30
Chloride(Cl^-) (mg/l)	24.82	35.25	122.12	36.24	78.41	56.09	80.00	86.38	99.78	34.75	100	250	250
Nitrate (NO_3^-) (mg/l)	8.62	22.10	9.00	11.60	16.20	14.30	18.20	10.30	14.00	32.60	10	50	10
Sulphate (SO_4^{2-}) (mg/l)	45.00	36.31	62.77	66.30	64.40	41.87	71.46	36.42	68.47	50.42	100	100	500
Total hardness (TH) ($CaCO_3$/ $MgCO_3$) (mg/l)	40.00	44.20	95.60	38.80	133.0	37.60	28.80	35.20	30.80	104.00	100	150	200

***NA – Not available, NAFDAC - National Agency for Food Drug Administrative Control, NSDWQ - Nigerian Standard of Drinking Water Quality, WHO - World Health Organization**

Table 2: Correlation analysis of trace elements in water samples of hand-dug well in the study area

	Fe	Ni	Cd	Hg	Mn	Pb	Cu	Zn	F
Fe	1	-0.356	-0.213	-0.541	-0.182	0.250	-0.311	-0.250	0.164
Ni		1	0.157	-0.316	0.295	-1.560	0.275	0.533	0.146
Cd			1	0.182	-0.254	-0.398	0.280	0.075	0.504
Hg				1	-0.309	-0.094	-0.240	-0.264	-0.212
Mn					1	0.068	0.274	0.173	-0.495
Pb						1	-0.561	-0.748	-0.188
Cu							1	0.700	0.188
Zn								1	0.287
F									1

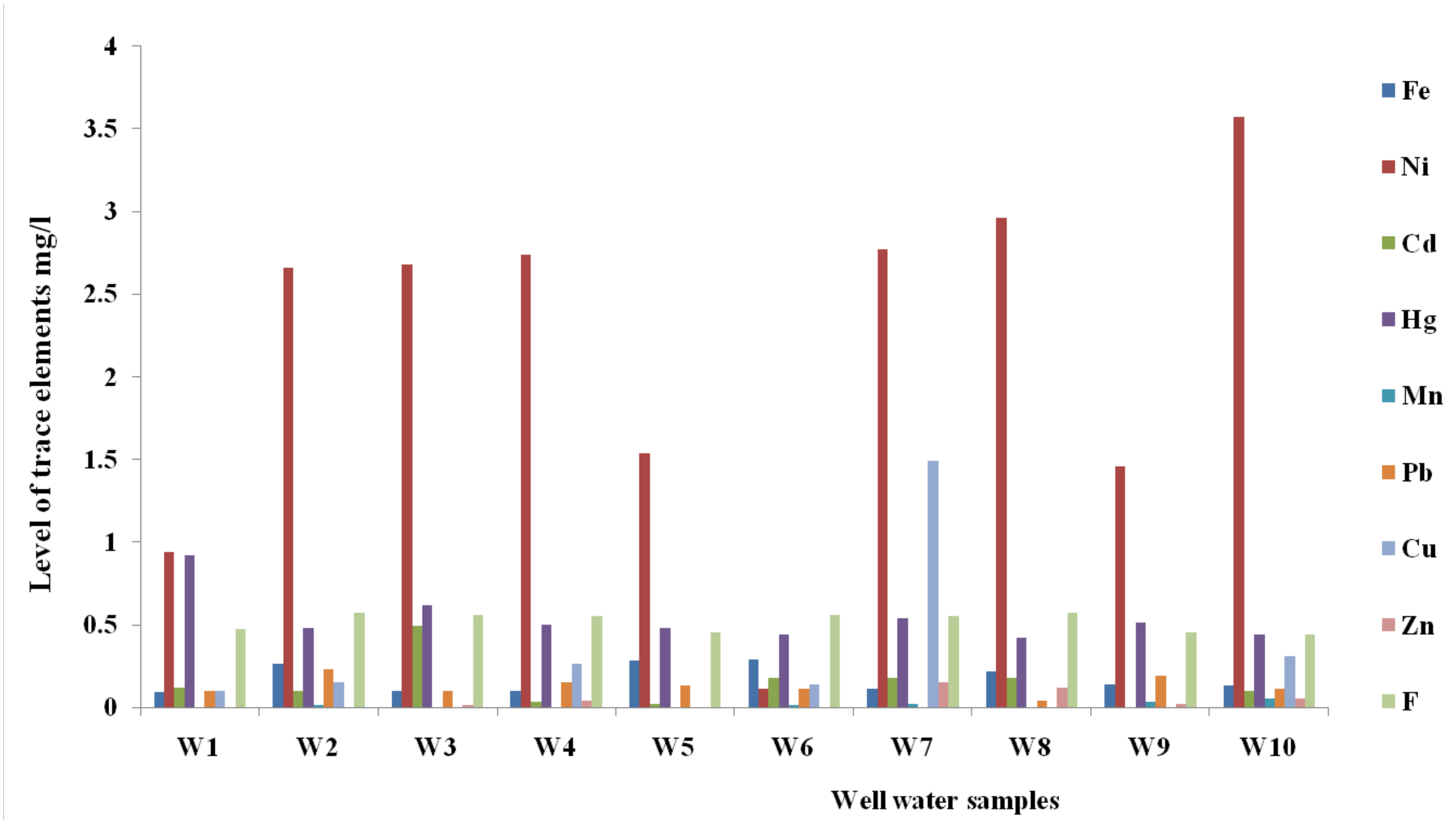

Figure 2: Levels of trace elements in well water samples in the study area

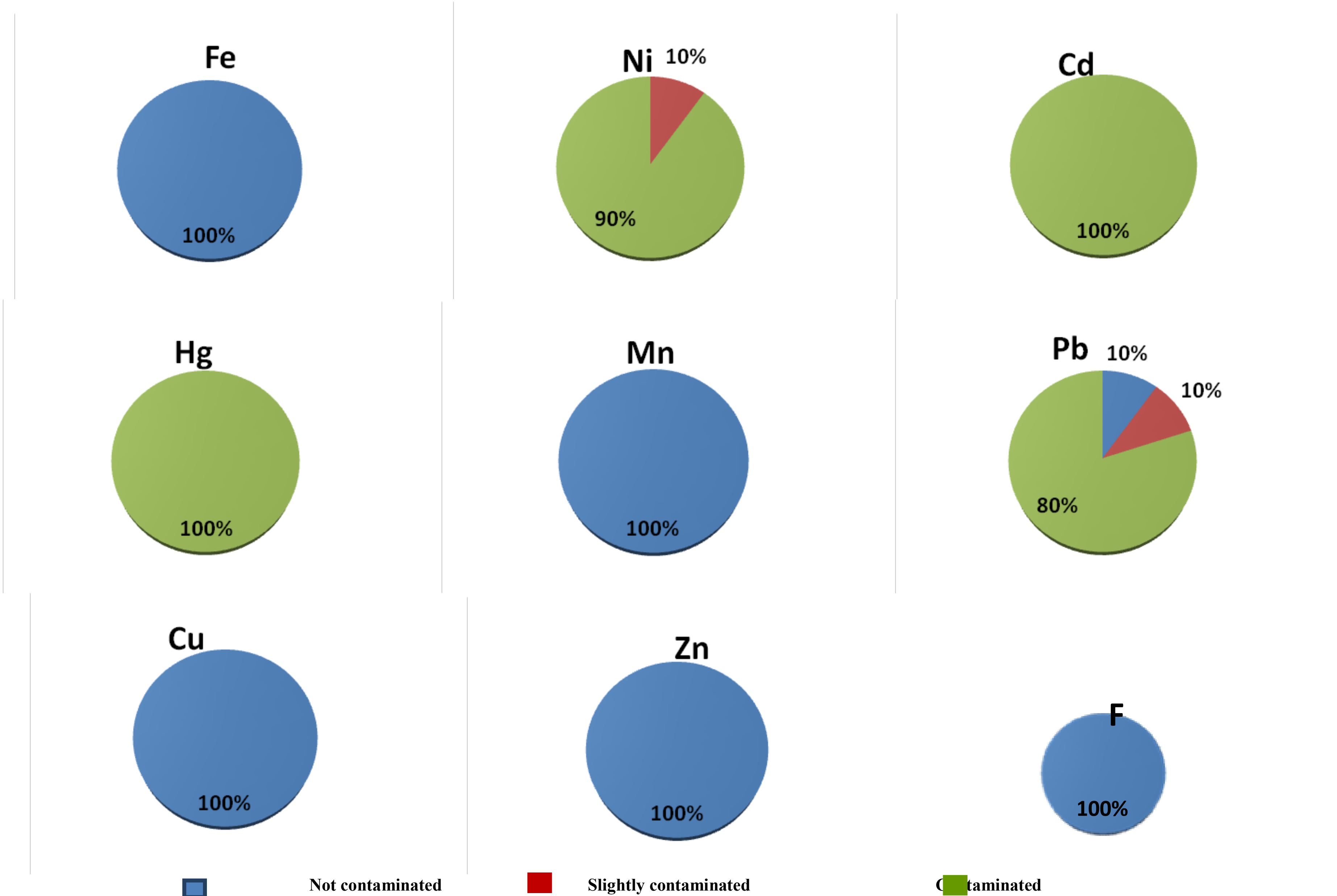

Figure 3: Contamination index (CI) ofwater samplesof hand-dug wellin the study area

3.4 Human health risk assessment

The results of hazard quotient (HQ) and hazard index (HI) for oral route estimated for both children and adults in the study area are presented in **Table 3 and Figure 4** respectively.

3.4.1 Non-carcinogenic health risk

As presented in **Table 3**, the HQ for Fe, Ni, Cd, Hg, Mn, Pb, Cu and Zn in water samples from hand-dug well in localities of Abakaliki via oral route revealed that Ni, Cd, Hg and Pb would generally elicit non-carcinogenic health hazard in both children and adult has these elements had HQ values > 1 except for Ni in W6 (Rice Mill), Cd in W9 (New Layout), Pb in W7 (Iyiokwu) and W8 (for adult only). However, HQ value was extremely high for Hg (93.38 – 370.56 for children and 47.60 – 111.17 for adults) in all the wells but it was lowest for Zn. HQ values for both children and adults in all the wells were < 1 for Fe, Mn, Cu (except in W7) and Zn. The order of HI for both children and adults in the wells was W4 < W1 < W3 < W7 < W2 < W8 < W10 < W6 < W9 < W5. The range of values of HIdue to the eight trace elements estimatedvia oral route for children and adultsin the samples were 120.78 – 391.30 and 61.57 – 121.26 respectively.

3.4.2 Carcinogenic health risk

The calculated cancer risk index (CRI) for Pb via oral route in children and adults is presented in **Figure 5**. Except W7 (Iyiokwu) where Pb was not detected, the CRI for the metal in children and adults was not within the acceptable range in all the wells.The order of CRI in the well to both children and adults was W8 < W1 = W3 < W6 = W10 < W5 < W4 < W9 < W2. The CRI range in children was 2.67E-3 – 1.53E-2 and in adults was 1.36E-3 – 7.83E-3. W2 (Mile 50) had the highest CRI while the least was recorded in W8 (CAS).

Table 3: Hazard quotient (HQ) of toxic elements in well water samples in the study area

Element	Age group	Well water samples									
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Fe	Children	0.02	0.06	0.02	0.02	0.06	0.06	0.02	0.05	0.03	0.03
	Adult	0.01	0.03	0.01	0.01	0.03	0.03	0.01	0.03	0.02	0.02
Ni	Children	3.14	8.87	8.94	9.14	5.14	0.37	9.24	9.87	4.87	11.91
	Adult	1.60	4.52	4.56	4.66	2.62	0.19	4.71	5.03	2.48	6.07
Cd	Children	16.01	13.34	65.37	4.00	2.67	24.01	24.01	24.01	NE	13.34
	Adult	8.16	6.80	33.32	2.04	1.36	12.24	12.24	12.24	NE	6.80
Hg	Children	204.50	106.72	137.85	370.56	106.72	97.83	120.06	93.38	113.39	97.85
	Adult	104.27	54.40	70.27	111.17	54.40	49.87	61.20	47.60	57.80	49.87
Mn	Children	NE	0.03	NE	NE	NE	0.03	0.07	NE	0.10	0.17
	Adult	NE	0.02	NE	NE	NE	0.02	0.04	NE	0.05	0.09
Pb	Children	4.76	10.96	4.76	7.15	6.19	5.24	NE	1.91	9.05	5.24
	Adult	2.43	5.59	2.43	3.16	3.16	2.67	NE	0.97	4.61	2.67
Cu	Children	0.17	0.25	NE	0.43	NE	0.23	2.48	NE	NE	0.52
	Adult	0.09	0.13	NE	0.22	NE	0.12	1.27	NE	NE	0.26
Zn	Children	NE	NE	2.22E-3	8.89E-3	NE	NE	0.03	0.03	4.45E-3	1.11E-2
	Adult	NE	NE	1.13E-3	4.53E-3	NE	NE	0.02	0.01	2.27E-3	5.67E-3

*NE – not estimated due to non-detection of the metals in the sample

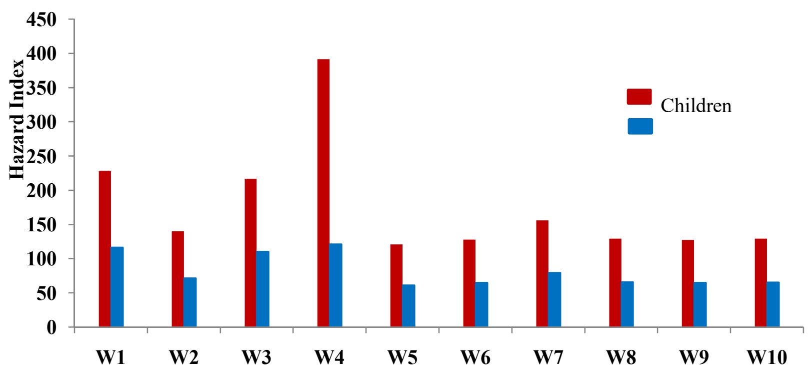

Figure 4: Hazard index (HI) of well water samples in the study area

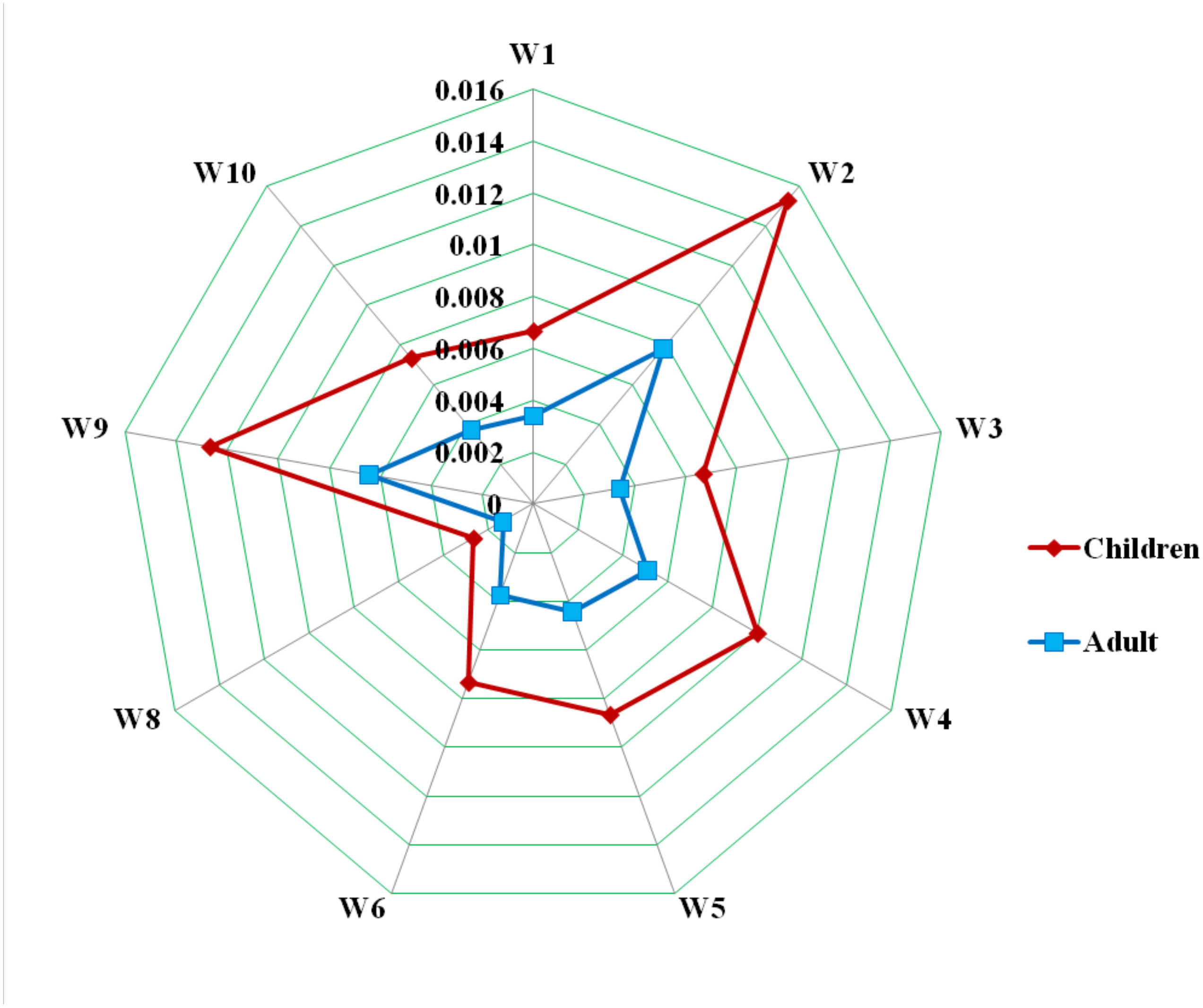

Figure 5: Cancer risk index (CRI) of well water samples in the study area

4.0 DISCUSSION

Hand-dug wells are popular water source in non-riverine area of Nigeria. However, requisite chemo-geological and quality assessment before and after the constructions of hand-dug wells are hardly done. In addition, hand-dug wells are poorly maintained despite their propensity to be contaminated by anthropogenic xenobiotic agentsdue to their relative openness and shallowness compared to borehole.Temperature of well water samples in the study area was ambient as recommended by regulatory agencies such as NAFDAC, NSDWQ and WHO. Nevertheless, the ambient temperature of water is not enough to adjudged it fit for drinking as temperature of water is dependent on prevailing weather condition except in case of direct thermal pollution from industries. The low pH in most of the well could be as a result of depositionof non-metallic oxides from anthropogenic sources such as vehicular exhaust into the wells. Slight acidity may enhance mobility and bioavailability of toxic elements in environmental matrix **(Kim *et al*., 2004)** which upon exposure may alter pH-sensitive biochemical processes in humans.

Electrical conductivity (EC) indicates the presence of dissolved ions which are largely determined by rainfall intensity and runoff **(Oyebamiji*et al*., 2017)**. It signifies the total amount of salt in dissolved form and measures the capability of water to convey electric current. The low level of EC in the water samples in the study area could be due to the sampling period when there was no rainfall and as such, run-off is minimal. Similarly, the moderate levels of total solids (TS), total dissolved solids (TDS) and total suspended solids (TSS) in the wells could be linked to the dry season when samples were collected. However, the relatively high level of TSS in sample from Mile 50 (W2) could be as a result of atmospheric deposition of low density solids from nearby anthropogenic activities.

Chloride (Cl^-) is an indicator of sewage contamination (Patil and Patil, 2010). Water sample from Kpirikpiri (W3) might be contaminated from nearby sewer as it had high Cl^- concentration. Sewage and other wastes rich in nitrate (NO_3^-) are potent in increasing the level of NO_3^-in any environmental matrix. Therefore, wells in Mile 50 (W2), Presco (W4), Spera-in-Deo (W5), Rice Mill (W6), Iyiokwu (W7), New Layout (W9) and Hilltop (W10) are probably receiving seepage contaminated with sewage. Catharsis, dehydration and gastrointestinal irritation have been linked to high concentration of sulphate (SO_4^{2-}) (Chavan and Zambare, 2014). Although, concentrations of SO_4^{2-}recorded in water from all the sampled wells were within the acceptable limit but long term exposure may result into accumulative toxicity. Hardness increases the boiling point of water and retard lather formation with soap due to the presence of calcium and magnesium salts **(Shrinivasa and Venkateswaralu, 2000)**. W5 and W10 might have high level of calcium and/or magnesium salts in its parent rock.

The low level of Fe recorded in all the samples could be due to its low level in the underlying parental rock or low geochemical interaction between the parental rock and the groundwater because Fe contamination is largely due to natural phenomenon **(Oyebamiji*et al*., 2018)**. This is opposed to the findings of **Odukoya *et al.* (2017)** where they attributed high Fe level in surface water to interaction between host rock and the surface water.Elevated concentration of Ni has been implicated to cause asthma, fibrosis conjunctivitis and cancer of respiratory pathway **(Hussain*et al*., 2019)**. Presence of Cd and Hg in water are linked to leaching from discharges from mining and chemical industries. Pb causes mental retardation in children and different types of cancer in human **(Surendran and El-Fawal, 2008)**. Therefore, high level of Ni, Cd, Hg and Pb contamination in the ten water samples from the wells might be a considerable justification for the inhabitants of the study area to cease from drinking from the wells. However, continuous intake of low levels of Mn, Cu, Zn and F as recorded in most of the well sampled might have chronic effects.

Trace elements with positive correlation signify source relatedness in terms of geogenic and/or anthropogenic processes. That is, these elements may be released from the same source into the underground hydrological system **(Florea *et al*., 2005)**. Meanwhile, negative correlation implies that the presence or increase in the level of one element retard the level of the other. No correlation therefore indicates that the elements are not emitted from the same source and may differ in geochemical behaviour.

Contamination index has become an essential tool to measure the degree of contamination due to elevated concentration of toxic elements **(Sundaray *et al*., 2011)**. High contamination index shows that the level of element is very well above the regulatory limit while slight contamination indicates that the metal is moderately above the limit. The contamination of all the wells due to Cd and Hg suggests serious health concern. In addition, the high percentage contamination of the wells by Ni and Pb calls for serious sensitization of the inhabitants.

Health risk assessment which is the evaluation of the potential adverse effects that can result from consuming certain substances or exposure to environmental xenobiotic agents is essential in environmental health and safety. Hazard quotient (HQ) > 1 implies that non-carcinogenic health risk would be elicited upon exposure to the environmental matrix. From this study, Ni, Cd, Hg and Pb would cause different non-carcinogenic health hazard in children and adults that drink from the majority of the wells. The highest non-carcinogenic health risk in this study is due to Hg. Also, it can be deduced from the study that HQ due to oral consumption of Fe, Mn, Cu and Zn in all the well water was within acceptable level of non-carcinogenic adverse health risk and therefore would not pose health hazard to both age groups.

Hazard index (HI) which is the summation of HQ of all elements in each well was > 1. This shows that none of the well has HI value within the acceptable level of non-carcinogenic adverse health risk. This is findings is similar to previous studies **(Khan *et al*., 2013; Hussain *et al*., 2019)**. Hence, none of the wells is fit for drinking both by children and adults. However, W5 (Spera-in-Deo) would elicit the highest non-carcinogenic health risk, probably due to vehicular congestion in the area more than other localities as the location serves as centre connection various localities in Abakaliki.Well 2 (Mile 50) posed the greatest carcinogenic risk in both children and adults due to oral ingestion of Pb in the well water while W8 (CAS) posed the least risk of carcinogenesis. All the wells posed higher risk of carcinogenesis in children than in adults. This further corroborates the conclusion from the non-carcinogenic risk assessment that, none of the well water is fit for drinking.

5.0 CONCLUSION

This research focused on assessing the physico-chemical parameters and selected trace elements in hand-dug wells in ten localities of Abakaliki, Ebonyi State of Eastern Nigeria.pH values recorded were within a range of 4.50 - 7.67 with most of the water samples slightly acidic. This low pH level could enhance metal toxicity in human as a result increase in their mobility and bioavailability. The low EC, TS, TDS and TSS could be influenced by dry season when the sampling was done as there was no rainfall and run-off was negligible. Cl^-, NO_3^- and SO_4^{2-}concentrations in natural water have been reported to associate particularly with intrusions of sewage. Other sources could be industrial discharges and agricultural practices. Samples from Mile 50 (W2), Kpirikpiri (W3), Presco (W4), Spera-in-Deo (W5), Rice Mill (W6), Iyiokwu (W7), New Layout (W9) and Hilltop (W10) had high levels of one or more of the anions above the recommended limits. Meanwhile, the study revealed that W5 and W10 showed high TH of 133.00mg/l and 104.00mg/l respectively due to presence of calcium and/or magnesium salts.Generally, low levels of Fe, Mn, Cu, Zn and F were recorded in all or most of the wells. However, their long-term intake can have chronic effects. Conversely, high concentrations of Ni, Cd, Hg and Pb were quantified in all the wells. Ni which has been documented to cause asthma, fibrosis conjunctivitis and cancer of respiratory pathway at elevated concentration accounted for the most abundant trace element with a range of 0.11mg/l – 3.57mg/l in the wells.Negative and positive correlations accounted for 52.78% and 8.33% of elemental association respectively while no correlation accounted for 38.89%. None of the wells had contamination due to Fe, Mn, Cu, Zn and F. However, all of them had between 80% and 100% contamination by Cd, Hg, Ni and Pb. Non-carcinogenic health risk assessment revealed that HQ values > 1 except for Ni in W6, Cd in W9, Pb in W7and W8 (for adult only). However, HQ value was extremely high for Hg (93.38 – 370.56 for children and 47.60 – 111.17 for adults) in all the wells but it was lowest for Zn. The range of values of HI due to the eight trace elements estimated via oral route for children and adults in the samples were 120.78 – 391.30 and 61.57 – 121.26 respectively. CRI for the metal in children and adults was not within the acceptable range in all the wells.All the wells posed higher health risk of in children than in adults. Finally, based on these findings, none of the hand-dug well is fit as source of drinking water.

REFERENCE

[1] APHA (1998).Standard Methods for the Examination of Water and Wastewater. 17th Edn., APHA-AWWA-WPCF 1998. Washington D.C.

[2] APHA.(1995). Standard methods. 19th Edition. *American Public Health Association,* Washington, DC.

[3] Ayantobo, O. O., Oluwasanya, G.O., Idowu, O. A. and Eruola, A. O. (2012).Water quality evaluation of hand-dug wells in Ibadan, Oyo state Nigeria. *Hydrology for Disaster Management*, 231pp.

[4] Chavan, B.L. and Zambare, N.S. (2014). Physicochemical analysis of groundwater samples in Solapur City, Maharastra, India. *International Journal of Research in Civil Engineering, Architecture and Design*, 2(3): 7 – 12.

[5] Cheesbrough, M. (2006). *District Laboratory Practice in Tropical Countries,* Part 2. Cambridge University press, 143-157pp

[6] Florea, R.M., Stoica, A.I., Baiulesca, G.E. and Capota, P. (2005). Water pollution in gold mining industry: a case study in RosiaMontona district Romania. *Environ. Geol*., 48: 1132–1136.

[7] Hussain, S., Habib-Ur-Rehman, M., Khanam, T., Sheer, A., Kebin, Z. and

Jianjun, Y. (2019). Health risk assessment of different heavy metals dissolved in drinking water. *International Journal of Environmental Researhc and Public Health,* 16: 1737.

[8] Khan, K., Lu, Y., Khan, H., Zakir, S., Khan, S., Khan, A.A., Wei, L. and Wang, T. (2013). Health risks associated with heavy metals in the drinking water of Swat, northern Pakistan. *J. Environ. Sci*., 25: 2003–2013.

[9] Kim, Y.S., Park, H.S., Kim, J.Y., Park, S.K., Cho, B.W., Sung, I.H. and Shin, D.C. (2004). Health risk assessment for uranium in Korean groundwater. *J. Environ. Radioact*. 1: 77–85.

[10] Odukoya, A.M., Olobaniyi, S.B., Oluseyi, T.O. and Adeyeye, U.A. 2017.Health risk associated with some toxic elements in surface water of Ilesha gold mine sites, southwest Nigeria. *Environ. Nanotech. Monit. & Mgt.* 8: 290 – 296.

[11] Okonko, I. O., Ogunjobi, A. A., Kolawale, O. O., Babatunde, S., Oluwole, I., Ogunnusi, T. A., Adejoyi, O. D. and Fajobi, E. A. (2009). Comparative studies and microbial risk assessment of water samples used for processing frozen sea foods in Ojora-Olopa, Lagos state, Nigeria. *Environmental Journal of Agricultural Foods and Chemistry,* 8(6): 408-415.

[12] Oluwasanya, G. O. (2009). *Better safe than sorry:* Towards Appropriate Water Safety plans for urban supply systems in developing countries, PhD. Thesis, Cranfield University, U.K., 459pp.

[13] Oyebamiji, A., Amanambu, A., Zafar, T., Adewunmi, A.J. and Akinyemi, D.S. (2018).Expected impacts of active mining on the distribution of heavy metals in soils around Iludun-Oro and its environs, Southwestern Nigeria.*Environmental Chemistry, Pollution and Waste Management*, 4: 1495046.

[14] Oyebamiji, A., Odebunmi, A, Ruizhong, H. and Rasool A. (2017). Assessment of trace metals contamination in stream sediments and soils in Abuja leather mining, southwestern Nigeria. *Acta Geochemical*, available at https://doi.ord/10.1007/s11631-017-0256-1 .

[15] Patil, V.T. and Patil, P.R. (2010). Physicochemical analysis of selected groundwater samples of Amalner Town in Jalgaon District, Maharashtra, India. *E-Journal of Chemistry*, 7(1): 111 – 116.

[16] Population.City (2015) Population of Abakaliki in 2015.Accessed on: http://population.city/nigeria/abakaliki retrieved on 03/04/2020.

[17] Rezaeli, H., Zarei, A., Kamarehie, B., Jafari, A., Fakhri, Y., Bidarpoor, F., Karami, M.A., Farhang, M., Ghaderpoori, M., Sadeghi, H. and Shalyari, N. (2019). Levels, distributions and health risk assessment of lead, cadmium and arsenic found in drinking groundwater of Dehgolan's Village, Iran. *Toxicol. Environ. Health Sci*., 11(1): 54 – 62.

[18] Shrinivasa, R.B. and Venkateswaralu, P. (2000). Physicochemical analysis of selected ground water samples. *Indian Journal of Environ Protection*, 20(3): 161.

[19] Sundaray, S.K., Nayak, B.B., Lin, S. and Bhatta, D. (2011). Geochemical speciation and risk assessment of heavy metals in the river estuarine sediments—acasestudy. Mahanadi Basin, India. *J. Hazard. Mater*. 186: 1837–1846.

[20] Surendran, G. and El-Fawal, H.A.N., 2008.Neuroimmune responses to toxic agents: Comparison of organometal electrophiles using detection of antibodies to neural cytoskeleton and myelin as biomarkers. *J. Pharmacol. Toxicol*. 3: 173 – 189.

[21] World Health Organization (2010). Guidelines for drinking water quality recommendations, Geneva, 1-6pp. Retrieved from: http://www.who.int/water-sanitationhealth/wHS-wwwD2010-guidelines2010-6-en. Assessed 13th June, 2018