Hydro-geochemical evaluation of groundwater quality in Akoko North West local government area of Ondo State, Nigeria

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ABSTRACT

A sudden geometric increase in population of Akoko North West Local Government Area of Ondo State has led to an increase in demand for water and harnessing of subsurface water reserve. A total of twenty six water samples obtained from both boreholes and hand-dug wells were analyzed for their physico-chemical characteristics with the aim of assessing their quality, usability and also to determine the level of their contamination in the local government which is dominated by granite gneisses, charnockites, and augen gneisses as the main rock types. The following physico-chemical properties were analyzed for in the samples collected: electrical conductivity (EC), pH, total alkalinity (TA), total dissolved solids (TDS), total suspended solids (TSS), acid neutralizing capacity (ANC) with major cations (Na^+, Mg^{2+}, Ca^{2+}), anions (PO_4^{3-}, HCO_3^-, SO_4^{3-}) and several heavy metals (Zn^{2+}, Fe^{2+}, As^+, Ni^+, Pb^{2+}, Cd^+, Cu^{2+}). The following results were obtained from the analysis: Zn^{2+} (0.109 – 0.437 ppm), Fe^{2+} (0.216 – 0.726 ppm), As^+ (0.01 – 0.03 ppm), Ni^+ (0.036 – 0.074), Pb^{2+} (0.003 – 0.010), Cd^+ (0.002 – 0.007), Cu^{2+} (0.086 – 0.241) with appreciable abundances of PO_4^{3-}, Cd^+, $Fe^{2+}$and Ni^+ some exceeding while some others are below the WHO acceptable level for drinking water, thereby making it a serious source of concern as it indicates varying levels of faecal contamination (from leaky septic tanks, interception with pit latrines) and heavy metal liberation into the water consumed by the residents. It was also noticed that the water was fresh based on the analysis of the Total Dissolved Solids and the Pb^{2+} concentrations almost exceeded the standard permissible limit. Generally, it was concluded that the overall quality of the ground water is averagely good physico-chemically.

Keywords: water samples; physico-chemical properties; water quality.

Avaliação hidrogeoquímica da qualidade da água subterrânea na área Akoko North West do governo local do estado Ondo, Nigéria

RESUMO

Um aumento geométrico e repentino da população da área de Akoko North West do Governo Local do Estado de Ondo levou a um aumento pela procura de água e aproveitamento de reserva de água subterrânea. As características físico-químicas de vinte e seis amostras de água obtidas de poços perfurados e cavados à mão foram analisadas com a

finalidade de avaliar sua qualidade, usabilidade e determinação de seu nível de contaminação na área do governo local, que é dominado principalmente pelas rochas de granito, gnaisses, charnockitos e augen gnaisse. As seguintes propriedades físico-químicas das amostras coletadas foram analisadas: condutividade elétrica (CE), pH, alcalinidade total (AT), sólidos totais dissolvidos (TDS), sólidos suspensos totais (SST), a capacidade de neutralização de ácido (CNA), com os principais cátions (Na^+, Mg^{2+}, Ca^{2+}), ânions (PO_4^{3-}, HCO_{3-}, SO_4^{3-}) e vários metais pesados (Zn^{2+}, Fe^{2+}, As^+, Ni^+, Pb^{2+}, Cd^+, Cu^{2+}). Os seguintes resultados foram obtidos: Zn^{2+} (0,109 – 0,437 ppm), Fe^{2+} (0,216 – 0,726 ppm), As^+ (0.01 – 0.03 ppm), Ni^+ (0,036 – 0,074), Pb^{2+} (0,003 – 0,010), Cd^+ (0,002 – 0,007), Cu^{2+} (0,086 – 0,241), com concentrações apreciáveis de PO_4^{3-}, Cd^+, Fe^{2+} e Ni^+ algumas superiores, enquanto outras abaixo do nível aceitável da WHO para água potável, fato que se constitui em grande preocupação, pois indica níveis variáveis de contaminação fecal (de vazamento de fossas sépticas e de latrinas) e contaminação de metais pesados na água consumida pelos moradores. Também foi observado que a água era doce com base na análise dos sólidos totais dissolvidos e que as concentrações de Pb^{2+} quase ultrapassaram o limite padrão estabelecido. Observou-se que a qualidade físico-química global da água do solo é medianamente boa.

Palavras-chave: amostras de água; propriedades físico-químicas; qualidade da água.

1. INTRODUCTION

Water is a very important component of the earthly environment. Throughout the history of man, water has always been sustaining life and serving communities. The importance of the quality of available water cannot, however, be over-emphasised. As far as Nigeria is concerned, there is abundant of surface and groundwater resources, particularly in the South-Western region which is entirely within the tropical rainforest zone (Obatoyinbo and Oyedotun, 2011). Rijswijk (1981) estimated the groundwater resources at $0 – 50m$ depth in Nigeria to be 6×10^6 km^3 (6×10^6 m^3). However, from the eight mega regional aquifers in Nigeria which Akujieze et al., (2003) estimated, the deposit of the total groundwater yields additional groundwater resources of 7.2 times Rijswijk's figure, the total of which is estimated to be 50 million trillion l/year (Akujieze et al., 2003). Earlier, Hanidu (1990) has estimated the surface water resources in Nigeria to be 224 trillion l/year. Hence, with the available surface water resources of 224 trillion litre per year (l/year) and about 50 million trillion l/year as groundwater resources, there is an assured water abundance in Nigeria. Any shortfall in meeting the rising population needs is principally due to harnessing, distribution, delivery and quality (Hanidu, 1990; Akujieze et al., 2003).

Through the International Drinking Water Supply and Sanitation Decade (1980 – 1990), the NPC (2006) recommended and proposed water for all by the year 2000. For this to be achieved, Nigeria launched a National Borehole Programme, which included 760 boreholes with only 228 (30%) being productive (Akujieze et al., 2003). The failure of this project may be due to poor knowledge of groundwater disposition in Nigeria, the bureaucratic nature of government projects or the attitude of new political government officials to discard their predecessors initiated projects, resulting in those ventures to be *white-elephant* projects. With the view and understanding that groundwater is much more of high quality than surface water (which are exposed to all sorts of pollution), individuals have been embarking on digging wells in their neighbourhood and apartments to meet their growing water needs for their multifarious purposes.

However, the quality of groundwater depends upon several factors such as lithology and conditions prevailing within formation, quantum of water available in the aquifer and its rate of circulation. Apart from these factors, the activities of microorganisms, temperature and pressure are also responsible for the chemical characteristic of groundwater (Ramanathan,

2004). Therefore, groundwater is not entirely pure water because it usually contains dissolved mineral ions (Okagbue, 1988). The type and concentration of these dissolved minerals can affect the usefulness of groundwater for different purposes (Boyle, 1988). If certain mineral constituent are present in excessive amounts, some type of treatment may be necessary to either change or remove the dissolved mineral before the water can be used for the intended purpose. The major cations found in groundwater include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and anions such as bicarbonate (HCO_3^-), sulphates (SO_4^{2-}), chloride (Cl^-) with non-ionic constituents like oxides, phenols, synthetic detergents, dissolved gases e.g. oxygen (O_2) and carbon dioxide (CO_2) (Tijani, 1994). These constituents result in the good quality of groundwater when they are present in optimum concentrations.

A sudden geometric increase in the population of Akoko North West Local Government of Ondo State, Nigeria which has reached 213,792 (UN, 2006) has led to an increase in the demand for water and harnessing of subsurface water reserve. This paper investigates the possible infiltration of dissolved mineral (either from weathered rock or anthropogenic sources) into subsurface water in the area (basement complex rocks), and comparing the mineral level with the set standard for quality water by the World Health Organization (WHO). The main objectives of this study are: to determine the suitability of the water in the study area for human consumption from WHO established standard, and to determine the level as well as source of contaminants where applicable. Physical tests and chemical tests for several parameters were also carried out using specific set of scientific experimental standard (Omotoyinbo and Okafor, 2008).

1.1. The Study Area

The study area (Akoko North West) is one of the eighteen Local Governments that made up Ondo State in the South-Western Region of Nigeria. It falls within latitudes 7°30′ and 7°35′N and longitudes 5°43′ and 5°49′E. The area is accessible by roads and footpaths and it occupies about 0.83km^2 in aerial extent (Figure 1). Topographically, the area is characterised by a relatively rugged, undulating, topography with outcrops of charnockites, migmatite gneiss with other gneissic rocks as highlands which range between 600 and 1500feet above sea level. It is situated within the Precambrian Basement Complex with the outcrops which are predominantly gneiss and migmatite (Figure 2). With this type of rock types, their ability to serve as aquifers compared to sedimentary aquifers is very minimal with limited small amount of groundwater storage within the crystalline basement. The failure rate of the new boreholes in the study area is as high as 80% (Edet et al., 1998), which is as a result of the geological configurations of the study area. The groundwater availability is, however, limited to fracture zones and areas of deep weathering. The topography of Ikare (the capital of the Local Government) is high with undulating relief of about 200m to more than 1500m high. There are knolls, ridges and flat lying exposures observed in the area. The western part is characterized by a conical hill relief – outcrops of batholiths is scattered in the southern part of the area towards Ikare and Okeagbe. Eastward, the area is featured by lowland outcrops and sparsely characterized with gneissic ridges. The major road runs from southwest to northwest.

The climate can be said to be subequatorial with two peaks of rainfall. The first peak comes up between April and July while the second peak comes up between late August and late October. These two peaks are marked by heavy rainfall and the mean annual rainfall is 1500 – 2000 mm with a relative humidity of about 75 - 95%. Since the climate is sub – equatorial, temperature could sometimes be severe. The mean annual temperature is 23 - 26°C (Duze and Ojo, 1982).

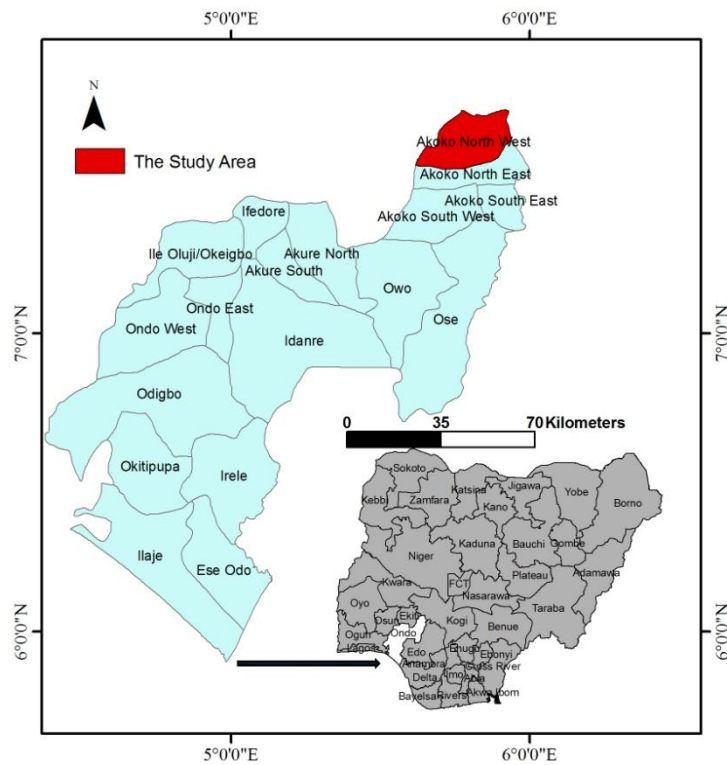**Figure 1.** Map of Ondo State Showing the study area. *Inset:* Map of Nigeria showing Ondo State.
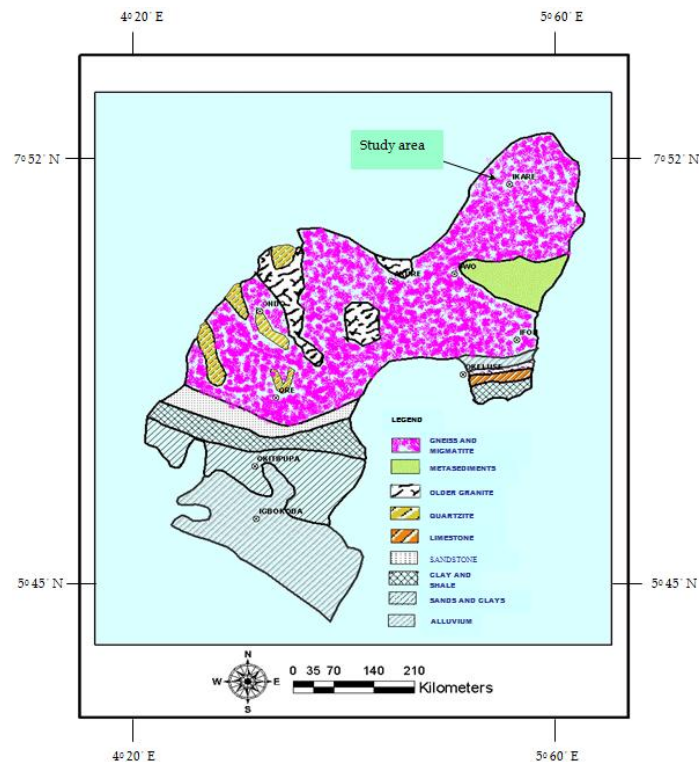

Figure 2. Geologic Map of Ondo State showing Geology and the location of the study area.
Source: Geological Survey Nigeria, Ondo State.

The area under study is situated in the deciduous rain forest area within south-western Nigeria. It has evergreen vegetation and urban settlement. The vegetation of this area reflects

the rainforest and Guinea Savannah's vegetation, which is characterized by different plants and trees which may reach a height of 5 m and even more. They consist of light forests, shrubs and scattered cultivation.

There are areas where rocks are covered by vegetation which is also an indication of the porosity of the rocks and function of the grain size. Trees and plants like timber, oil palm, kolanut, rubber, cocoa and citrus are very prominent in these areas. A high forest zone is found in the north while the southern part is mostly Sub-Savannah due to the farming activities in the area, which had actually reduced the thickly vegetated area.

2. MATERIAL AND METHODS

Groundwater samples were collected from the hand-held boreholes, Solar powered boreholes and hand-dug wells at various locations and different depths in the study area. The details of the sampling site and depths are given in Table 1 below. The samples were then taken to the International Institute for Tropical Agriculture (IITA), Ibadan, Oyo State of Nigeria for the analysis of all the parameters (physico-chemical parameters, cations, anions and the heavy metals), after which relevant statistical packages were also used to analyse the data and their level of significance was determined.

Table 1. Summary of the derivations from the GPS readings from sample collection and other readings.

S/n	Sample number (from selected locations)	Date	Time	Water Source	Depth (m)	Elevation (m)	Longitude	Latitude
1	I_1	20-02-10	12:58	HDW	6.1	393	05°46′15″E	07°32′37″N
2	I_2	20-02-10	1:31	HDW	6.1	392	05°46′07″E	07°32′12″N
3	I_3	20-02-10	1:49	HDW	5.5	396	05°45′52″E	07°32′03″N
4	I_4	20-02-10	2:01	HDW	6.1	405	05°45′45″E	07°32′00″N
5	I_6	20-02-10	2:45	HHBH	ND	409	05°45′37″E	07°31′59″N
6	I_7	20-02-10	3:18	SBH	ND	421	05°45′34″E	07°31′44″N
7	I_8	20-02-10	3:36	HHBH	ND	405	05°46′12″E	07°31′30″N
8	I_9	20-02-10	3:46	HHBH	ND	417	05°45′33″E	07°31′29″N
9	I_{10}	20-02-10	4:03	HHBW	ND	450	05°45′22″E	07°31′21″N
10	I_{11}	20-02-10	4:48	HDW	ND	452	05°44′57″E	07°31′18″N
11	I_{13}	20-02-10	5:28	HHBH	ND	462	05°44′51″E	07°30′00″N
12	A_1	19-02-10	12:15	HDW	6.7	363	05°46′43″E	07°33′04″N
13	A_3	20-02-10	11:29	HDW	6.1	410	05°46′50″E	07°33′12″N
14	A_4	19-02-10	12:46	HDW	9.2	407	05°46′48″E	07°33′10″N
15	A_6	19-02-10	1:12	HDW	6.1	403	05°46′42″E	07°33′07″N
16	A_7	19-02-10	1:36	HDW	5.5	402	05°46′28″E	07°33′08″N
17	A_9	19-02-10	1:54	HDW	7.3	393	05°46′17″E	07°33′11″N
18	A_{10}	19-02-10	2:55	HHBH	ND	403	05°45′46″E	07°33′48″N
19	A_{11}	19-02-10	3:21	HDW	9.8	404	05°46′01″E	07°33′38″N
20	A_{13}	19-02-10	4:03	HDW	6.7	397	05°46′06″E	07°33′12″N
21	A_{14}	19-02-10	4:25	HDW	7.3	396	05°46′06″E	07°32′52″N
22	A_{15}	19-02-10	4:44	HDW	7.3	389	05°46′12″E	07°32′46″N
23	M_2	20-02-10	11:03	HDW	6.7	410	05°46′35″E	07°32′57″N
24	M_3	20-02-10	11:13	HDW	7.9	410	05°46′37″E	07°33′02″N
25	M_4	20-02-10	12:03	HDW	9.7	408	05°46′27″E	07°32′48″N
26	M_6	20-02-10	12:18	HDW	7.3	405	05°46′30″E	07°32′41″N

Note: I = Ikare; A = Arigidi; M = Ministry Area; HHBH = Hand – held Borehole; SBH = Solar Borehole; HDW = Hand – dug well; ND= No Data.

Magellan SporTrak® handheld Global Positioning System (GPS) Receivers device with 12-channel tracking and differential correction capability was used to determine and identify location where the water samples are selected, especially with the aid of a topographical map covering the study area. The SporTrak Map GPS used can track up to 12 satellites at any time out of the current constellation, and it fully supports the Wide Area Augmentation System (WAAS) with the accuracy within 3 metres or better depending on the line of sight to the satellite. Tape rule and sample bottles are other materials made use of in the field.

Twenty six water samples were collected from various locations in the Local Government Area on the 19th and 20th of February 2010 and the samples were used for the assessment of water quality which comprise nineteen hand dug wells and seven boreholes (examples of which are shown in Figure 3 below). These constitute the major sources of water for the inhabitants. About 20 millilitres of water samples were collected from both the hand dug wells and boreholes into clean plastic containers. The samples were then labelled and preserved (in the refrigerator) until they were taken to the laboratory for chemical analysis. The water samples were analyzed for electrical conductivity (EC), pH, total alkalinity (TA), total dissolved solids (TDS), total suspended solids (TSS), acid neutralizing capacity (ANC) with major cations (Na^+, Mg^{2+}, Ca^{2+}), anions (PO_4^{3-}, HCO_3^-, SO_4^{3-}) and several heavy metals (Zn^{2+}, Fe^{2+}, As^+, Ni^+, Pb^{2+}, Cd^+, Cu^{2+}) using the Buck Model 205 Atomic Absorption Spectrophotometer and flame photometer for the cations.

| (a) Hand-Held Borehole | (b) Solar-Powered Borehole | (c) Hand-Dug Well |

Figure 3. Example of (a) Hand Held Borehole, (b) Solar Powered Borehole and (c) Hand-dug well in the study area.

The chemical character of any water determines its quality and utilization. The quality is a function of the physical, chemical and biological parameters and could be subjective since it depends on a particular intended use (Tijani, 1994). Hence, there are different water quality standards and are generally based on two main criteria. These include the presence of objectionable taste, odour and colour plus the availability of substances with adverse physiological health effects (Tijani, 1994).

The quality of water, whether it is used for drinking, irrigation or recreational purposes is significant for health in both developing and developed countries worldwide. Water quality can have a major impact on health, either through outbreaks of waterborne diseases or by contributing to the background rates of the diseases. Accordingly, countries develop water quality standards to protect public health (Ramanathan, 2004).

The WHO has developed a series of normative guidelines for assessment of health risk and hazards through water. These principal guidelines are intended to assist countries in

establishing effective national or regional strategies and standards. The physical parameters such as pH, EC, TDS etc and chemical parameters such as Ca^{2+}, Mg^{2+}, Na^+, Fe^{2+}, Cl^-, SO_4^{2-} with other heavy metal concentrations should be within the WHO acceptable standards. Therefore, the findings from the analyses are compared with WHO set standard to evaluate the groundwater quality in the local government (the study area). The World Health Organization (WHO, 1984) recommended a standard for drinking water quality. Table 2 below gives the example of these recommendations.

Table 2. Summary of Physical and Chemical Characteristics and WHO (1984) standards for drinking water.

Measured Parameter	Range	GW*	SW*	Overall mean	Acceptable Level	Maximum Permissible Level
Temperature (°C)	24.20 – 28.20	27.17	24.96	26.37		
pH (pH Unit)	7.10 – 9.10	7.91	7.70	7.83	6.6	8.5
EC (ms/cm)	6.00 – 12.72	437.59	106.00	318.22	-	1400.00
TH (mgL^{-1})	1.21 – 65.36	16.14	3.84	11.71	-	
TDS (mgL^{-1})	10.32 – 763.20	250.98	46.50	177.40		1000.00
SAR (mgL^{-1})	0.15 – 3.89	0.56	0.99	0.77		
Ca^{2+} (mgL^{-1})	1.00 – 130	45.75	4.39	30.86		200.00
Mg^{2+} (mgL^{-1})	1.10 – 9.72	4.58	3.97	4.36		
Na^+ (mgL^{-1})	1.40 – 28.00	11.61	7.46	10.11		200.00
K^+ (mgL^{-1})	2.0 – 65.0	19.08	7.17	14.79		
Fe^{2+} (mgL^{-1})	0.05 – 0.60	0.19	0.14	0.17	0.3	1.00
HCO_3^- (mgL^{-1})	3.05 – 97.6	31.71	25.82	29.59		
Cl^- (mgL^{-1})	2.84 – 60.35	29.91	18.13	26.67		250.00
SO_4^{2-} (mgL^{-1})	0.01 – 5.93	1.40	1.64	1.49	200.00	400.00
PO_4^{3-} (mgL^{-1})	0.01 – 0.03	0.01	0.01	0.01		
NO_3^- (mgL^{-1})	1.00 – 7.46	3.81	6.39	4.74		10.00

GW*= Groundwater; EC = Electrical Conductivity; TH = Total Hardness; SAR = Sodium Absorption Ratio; SW* = Surface water (mean concentration) for each group; TDS = Total Dissolved Solid.
Source: World Health Organization (1984, 1997)

3. RESULTS

The analysis of the findings, which is centred on laboratory test of the water samples collected from both (mechanical and solar powered) boreholes and hand-dug wells and are termed to be ideal for human consumption, are compared with the WHO standards for drinking waters.

The analysis is presented by plotting the concentration of the analytical values of each element and the WHO standard in mgL^{-1} (ppm) with the twenty – six sample locations so as to have an overview of the concentration of each element and its probable effect on the quality of the water. The results of the analysis are presented in Tables 3 – 4. The derived results from the analysis are then plotted in comparison with the WHO stand values, the bar chart of which are presented in Figures 4 - 6. The elements analyzed are Ca, Mg, Na, As, Fe, Zn, Cu, Cd, Pb and Ni.

Table 3. The concentrations of Anion, Cation and heavy metal from the water samples at the study area.

Sample Particulars	mgL^{-1}												
	Ca^{2+}	Ni^+	Fe^{2+}	Cu^{2+}	Zn^{2+}	Cd^+	As^+	Pb^{2+}	Mg^{2+}	Na^+	HCO_3^-	SO_4^{2-}	PO_4^{2-}
I_1	11.117	0.071	0.521	0.106	0.169	0.006	0.002	0.008	5.011	21.081	0.018	0.026	0.041
I_2	9.856	0.056	0.561	0.136	0.248	0.005	0.001	0.009	4.220	19.322	0.015	0.029	0.039
I_3	11.327	0.066	0.521	0.098	0.165	0.007	0.003	0.008	5.026	20.056	0.019	0.031	0.044
I_4	12.170	0.053	0.513	0.241	0.388	0.007	0.002	0.007	5.716	18.716	0.021	0.026	0.042
I_6	9.986	0.066	0.608	0.161	0.297	0.005	0.002	0.009	4.218	21.732	0.017	0.029	0.037
I_7	10.771	0.059	0.613	0.217	0.402	0.005	0.003	0.007	4.761	20.156	0.019	0.018	0.039
I_8	10.350	0.049	0.512	0.206	0.351	0.004	0.002	0.010	4.113	21.520	0.013	0.029	0.041
I_9	9.988	0.056	0.518	0.116	0.306	0.006	0.002	0.008	4.216	19.116	0.015	0.031	0.042
I_{10}	11.731	0.058	0.498	0.224	0.437	0.006	0.003	0.009	5.005	21.681	0.013	0.026	0.043
I_{11}	10.156	0.058	0.601	0.185	0.372	0.004	0.002	0.010	4.371	17.115	0.014	0.036	0.041
I_{13}	12.001	0.061	0.533	0.177	0.298	0.005	0.002	0.008	5.296	19.781	0.016	0.028	0.083
A_1	8.176	0.036	0.351	0.111	0.167	0.002	0.001	0.005	3.005	14.216	0.011	0.017	0.019
A_3	8.151	0.041	0.314	0.132	0.121	0.002	0.001	0.004	3.256	16.081	0.010	0.014	0.021
A_4	9.086	0.039	0.298	0.091	0.136	0.003	0.002	0.005	1.986	13.713	0.012	0.021	0.024
A_6	10.722	0.044	0.341	0.106	0.203	0.002	0.001	0.005	2.013	12.118	0.010	0.015	0.018
A_7	9.165	0.043	0.288	0.116	0.213	0.003	0.001	0.005	1.965	11.811	0.009	0.017	0.022
A_9	8.986	0.039	0.216	0.092	0.167	0.004	0.002	0.004	2.850	13.381	0.013	0.014	0.021
A_{10}	8.932	0.041	0.306	0.086	0.143	0.003	0.002	0.006	2.117	12.156	0.012	0.021	0.019
A_{11}	9.006	0.036	0.281	0.095	0.147	0.004	0.002	0.003	2.658	13.118	0.012	0.020	0.022
A_{13}	9.156	0.039	0.269	0.089	0.132	0.003	0.001	0.004	2.134	14.218	0.013	0.017	0.020
A_{14}	8.111	0.042	0.325	0.106	0.211	0.003	0.002	0.005	3.216	12.116	0.011	0.015	0.018
A_{15}	8.635	0.046	0.341	0.093	0.123	0.004	0.002	0.004	3.186	13.148	0.012	0.019	0.020
M_2	12.167	0.041	0.726	0.113	0.109	0.007	0.003	0.009	7.114	26.081	0.017	0.031	0.053
M_3	13.151	0.069	0.691	0.094	0.120	0.008	0.003	0.009	7.215	24.115	0.015	0.029	0.049
M_4	11.328	0.074	0.688	0.121	0.307	0.007	0.002	0.008	6.932	25.168	0.019	0.033	0.048
M_6	14.715	0.073	0.701	0.091	0.140	0.008	0.003	0.010	7.910	27.108	0.017	0.034	0.151

Table 4. The concentrations of physical parameters from the water samples at the study area TDS (mgL^{-1}); TSS (mgL^{-1}).

Sample Particulars	pH	TA	ANC	EC (µS/cm)	TDS (mgL^{-1})	TSS (mgL^{-1})
I_1	6.3	0.011	0.121	29.33	12.411	6.74
I_2	6.1	0.009	0.133	31.18	13.086	7.02
I_3	5.9	0.010	0.107	26.72	11.917	5.99
I_4	6.5	0.011	0.206	29.75	14.086	6.36
I_6	5.8	0.117	0.126	32.68	15.137	6.41
I_7	5.7	0.092	0.096	31.77	12.929	7.22
I_8	6.1	0.106	0.086	29.84	13.756	7.14
I_9	5.7	0.006	0.132	27.56	15.225	5.89
I_{10}	6.5	0.011	0.141	29.72	17.986	7.02
I_{11}	6.8	0.009	0.126	32.08	14.756	6.41
I_{13}	5.6	0.006	0.134	31.11	15.090	5.88
A_1	4.7	0.011	0.109	21.15	9.750	4.71
A_3	5.0	0.008	0.113	19.85	10.332	5.05
A_4	4.7	0.009	0.121	23.66	9.851	4.93
A_6	4.9	0.010	0.097	20.11	11.033	4.67
A_7	5.3	0.007	0.113	21.56	9.748	5.13
A_9	6.0	0.010	0.086	23.35	8.996	5.04
A_{10}	5.9	0.009	0.114	21.65	10.826	4.79
A_{11}	6.1	0.008	0.106	19.84	11.047	4.82
A_{13}	5.3	0.009	0.114	22.31	10.251	5.36
A_{14}	5.5	0.010	0.098	18.56	8.744	7.21
A_{15}	4.9	0.007	0.097	19.74	10.256	6.84
M_2	6.9	0.013	0.023	36.08	14.117	9.35
M_3	7.1	0.012	0.021	39.75	16.032	8.96
M_4	6.6	0.013	0.019	35.11	15.056	9.44
M_6	6.5	0.011	0.021	40.08	14.136	10.13

TSS = Total Suspended Solids; ANC = Acid Neutralizing Capacity; EC = Electrical Conductivity; TA = Total Alkalinity; TDS = Total Dissolved Solid.
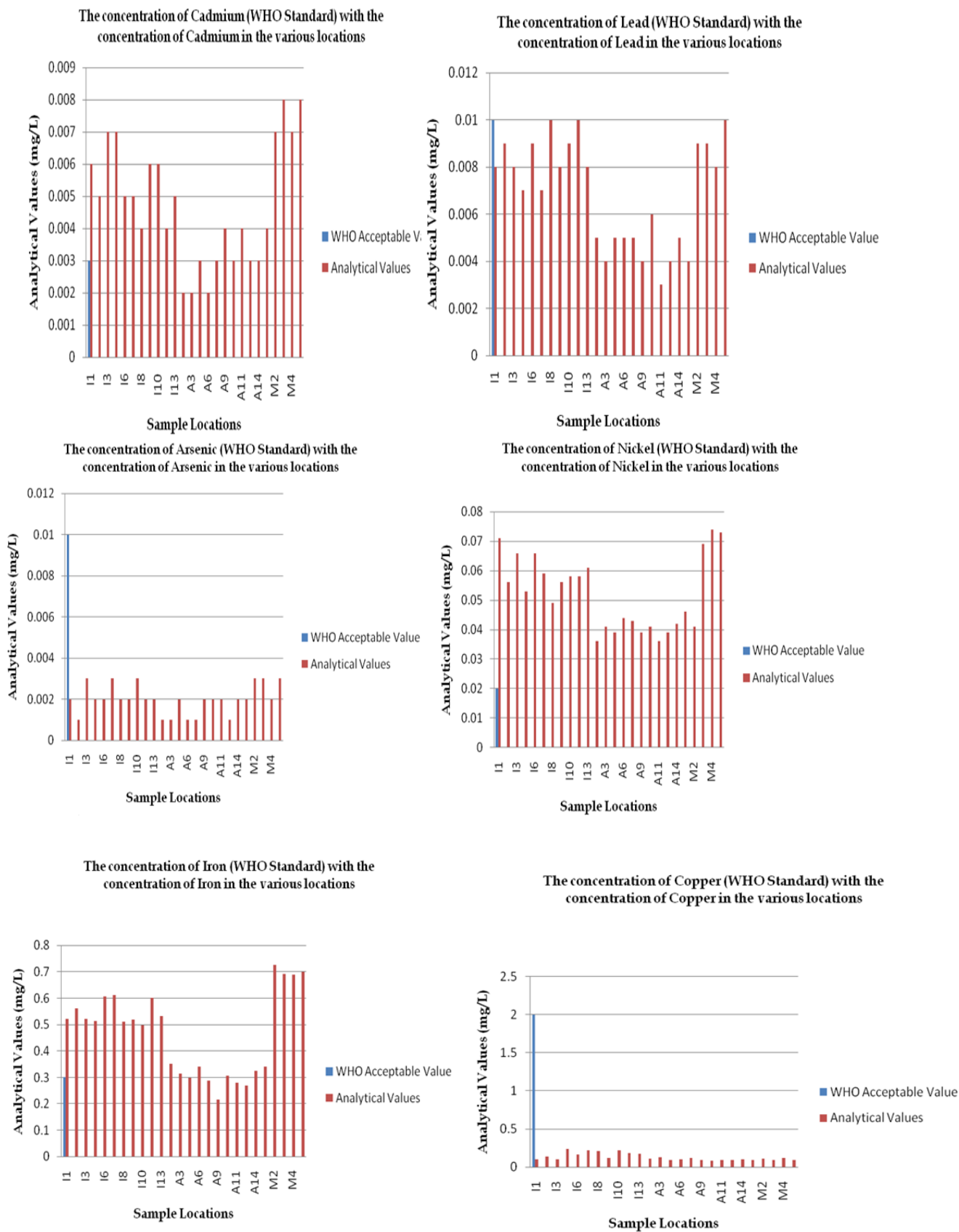
Figure 4. Graph of physico-chemical analytical values of groundwater samples with WHO Acceptable Value. (i) Cadmium (ii) Lead (iii) Arsenic (iv) Nickel (v) Iron and (vi) Cooper.
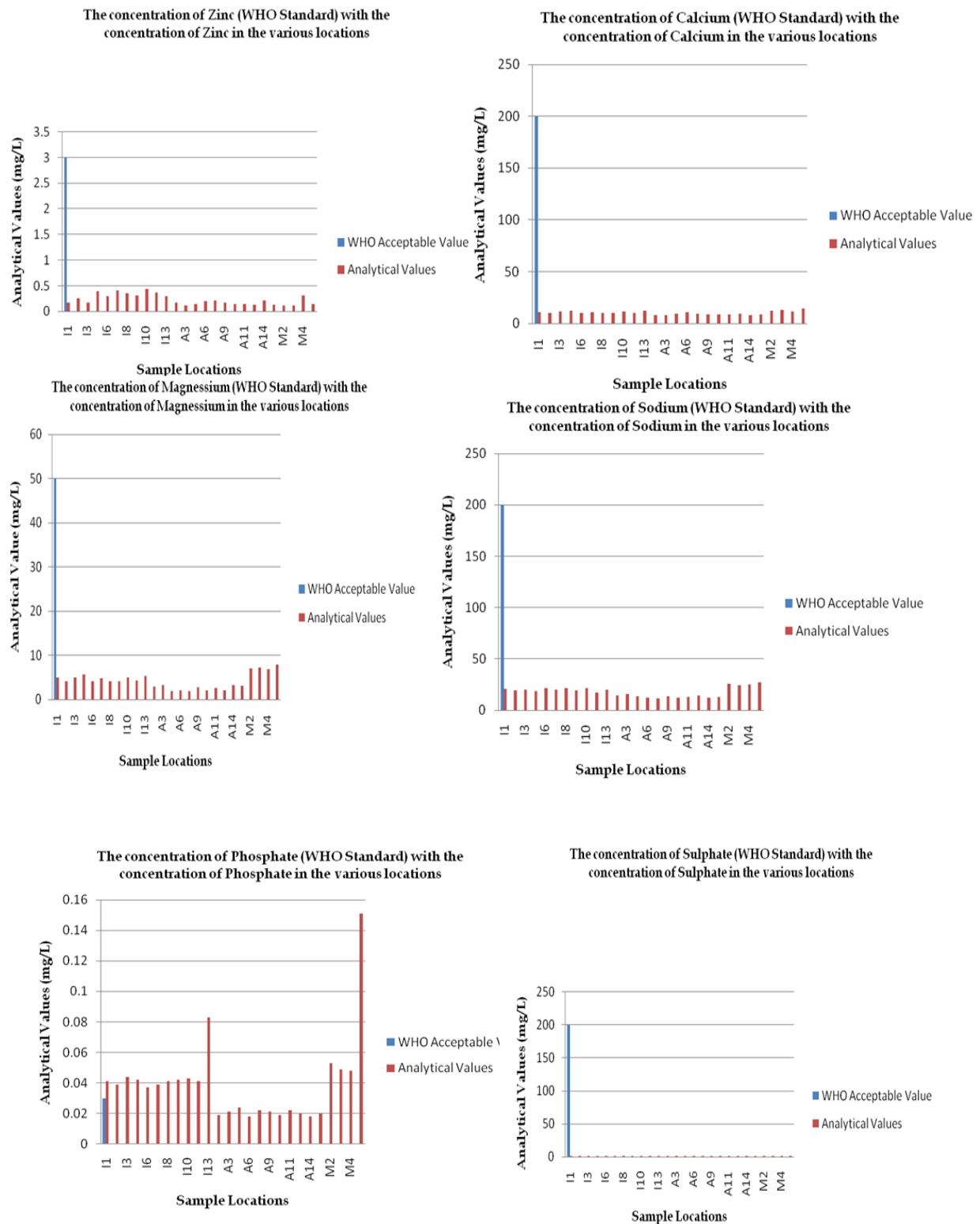
Figure 5. Graph of physico-chemical analytical values of groundwater samples with WHO Acceptable Value. (i) Zinc (ii) Calcium (iii) Magnesium (iv) Sodium (v) Phosphate and (vi) Sulphate.
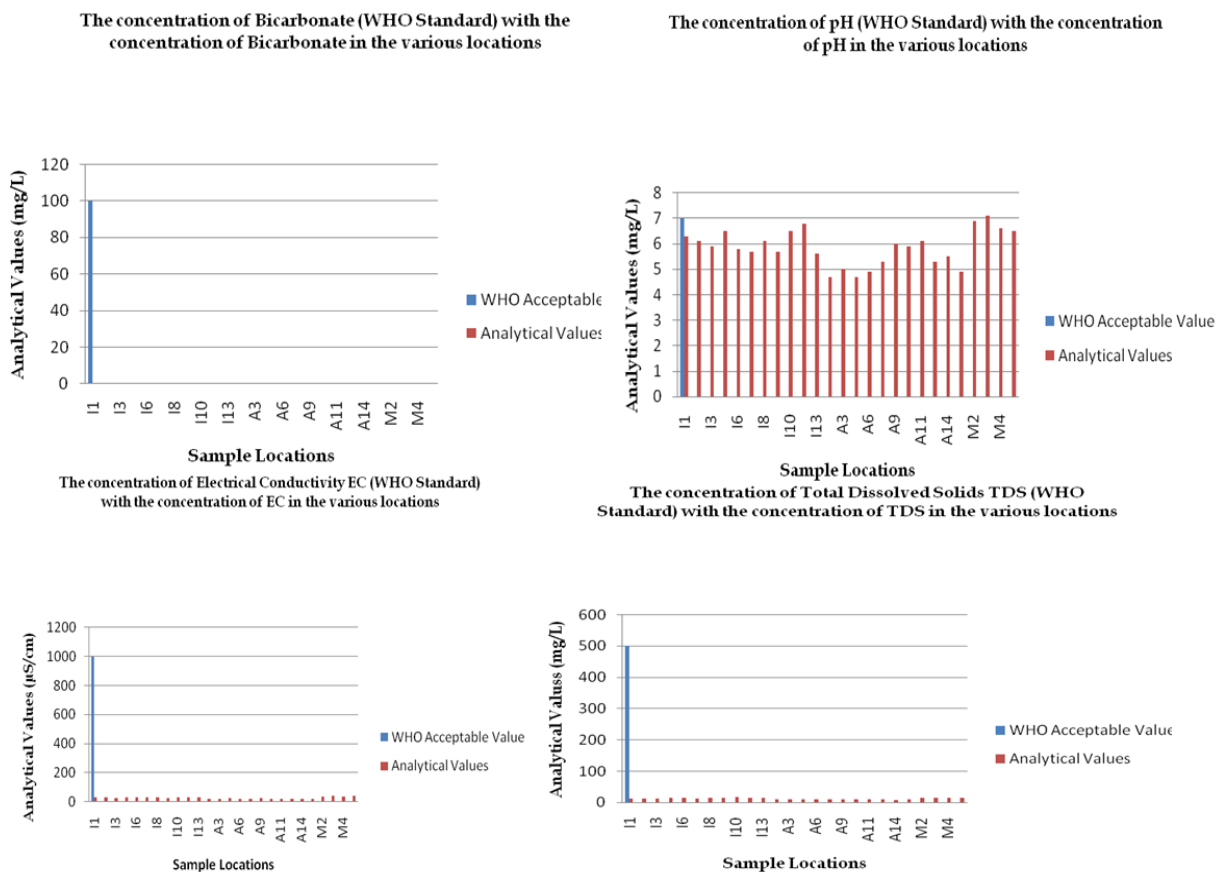
Figure 6. Graph of physico-chemical analytical values of groundwater samples with WHO Acceptable Value (i) Bicarbonate (ii) pH (iii) Electrical Conductivity (EC) and (iv) Total Dissolved Solids.

4. DISCUSSION

The characteristics of each element varies from one sample point to the other and this indicates the difference in the quality of the water sample collected from that particular point. The WHO acceptable values are then compared with the various values to determine and compare the suitability and effect of continual consumption of such water.

The Figures 4, 5 and 6 above indicate the comparison of the analysed values for the groundwater parameters in Akoko North West Local Government of Ondo State with the WHO established standard. For cadmium concentrations, the analyzed values of the samples taken at Arigidi-Akoko are the only ones within the WHO permissible range (0.003 mgL^{-1}) Figure 4(i), in other areas, the difference are less than the acceptable WHO standard concentration (0.003 mgL^{-1}), and are still assumed to be okay for domestic use except for two peaks at locations 9 and 11 in Arigidi. On the other hand, the analyzed values of the samples taken at Ikare and the Ministry area are far above the permissible concentration. It can therefore be concluded that the concentration of cadmium in these areas are anomalous and as such geological.

For the lead concentrations (Figure 4(ii)), the analyzed values fall within the permissible range for lead concentration based on WHO standard concentration (0.01 mgL^{-1}). It can therefore be concluded that though the concentration of the various sample locations have a concentration between the range, the lead intake of the residents within the study area is lesser than the acceptable which is what it ought to be since lead intake is hazardous to the health of man. Nevertheless care should be taken at the three locations (I_8, I_{11} and M_6) that have the

same lead concentration as the WHO standard overtime so that it does not exceed the acceptable values.

The WHO guideline value for arsenic in drinking water is currently 0.01 mgL^{-1} although the Nigerian National Standard is 0.05 mgL^{-1}. Few data are so far available for arsenic in groundwater from Nigeria (Smedley and Kinniburgh, 2002). However, from the Figure 4(iii), the analyzed values for the samples fall within the permissible range (0.001 mgL^{-1}, Table 2) for arsenic concentration but it is far less than the acceptable WHO standard concentration (0.01 mgL^{-1}). However, it should be noted the overall concentration which is lesser than the permissible value for arsenic is acceptable because too much arsenic intake is hazardous to human's health.

The overall analysis of the values for the groundwater sampled (See Tables 3 and 4, as well as Figures 4, 5 and 6) in comparison with the WHO acceptable standard (See Table 2) indicates that Copper (Figure 4(vi)), Zinc (Figure 5(i)), Calcium (Figure 5(ii)), Magnesium (Figure 5(iii)), Sodium (Figure 5(iv)), Sulphate (Figure 5(v)), Bicarbonate (Figure 6(i)), Electrical Conductivity – EC (Figure 6(iii)) and Total Dissolved Solids (Figure 6(iv)) are far lesser than the WHO acceptable standard(quality) for drinking water. The magnitude of the values for Nickel (Figure 4(iv)), Iron (Figure 4(v)) and Phosphate (Figure 5(v)) are, however, higher than the WHO established standard. The only groundwater quality parameter from the samples analysed for the study which is generally of WHO standard is the pH value (Figure 6(iv)).

Clear differences are observable in all the sampled groundwater from the Hand Held Boreholes, Solar-Powered Boreholes and Hand-Dug wells in the local government area. The summary of the effects of these variations to the human health is presented in Table 5 below. The major threats to the groundwater quality in the study area are from agricultural effluents seepage, septic tank and soak-away pits leakages, water table's interception with latrines and other various other impacts of human encroachment which do affect the physical and chemistry of the groundwater component in the area. Major anomalies are seen in the concentrations of some of the heavy metals in the area.

Table 5. The likely effect of metal ingestion above/below acceptable level.

Measured Parameters	Acceptable Level	Effect above/below level
Total dis.solids (TDS)	Max 1000	Stomach discomfort
Cadmium	0.003 mgL^{-1}	Kidney damage
Copper	2.0 mgL^{-1}	Gastrointestinal, liver or kidney damage
Temperature	25^{0}C	Bone disease (pain and tenderness of the bones); Children may get
Arsenic	0.01	Skindamage or problems with circulatory systems, and may have
Total hardness	Max 500	Increase in blood pressure
Chlorite	1.0	Anemia; infants & young children: nervous system effects
Turbidity	Max 25	Nausea, cramps, diarrhea, and associated headaches.
Chlorine	Max 200 mgL^{-1}	Eye/nose irritation; stomach discomfort
Calcium	Max 200 mgL^{-1}	Indigestibility of fat in the body
Magnesium	Max 150 mgL^{-1}	Gastrointestinal, liver or kidney damage
Potassium	Max 50	Effect on blood pressure
Lead	0.01 mgL^{-1}	Infants and children: Delays in physical or mental development; children
pH	6.5 - 8.5	Rusting, cancer
Aluminium	0.2 mgL^{-1}	Minor kidney changes
Nickel	0.02 mgL^{-1}	Cancer of lungs, nose, bone and dermatitis
Conductivity	Max	Anemia; liver, kidney or spleen damage; changes in blood
Iron	0.30 mgL^{-1}	Rusting, cancer
Sulphate	Max 400 mgL^{-1}	Allergic dermatitis
Sodium	Max 200 mgL^{-1}	Increased risk of cancer
Zinc	3.0 mgL^{-1}	Nausea, cramps, diarrhea, and associated headaches.

Source: WHO (1997).

5. CONCLUSION

It can be concluded that the sampled groundwater are in most cases not suitable for human consumption judging by the various concentrations of the physicochemical parameters analyzed from the samples. Because of the total reliance of the entire population in the study area on groundwater for their various uses, there is the need to carry out a research on the link between quality of water intake and the health conditions of the populace in the study area. It was also observed that some of the heavy metals, anions and cations, with the physical parameters are much higher than the WHO acceptable standard for drinking water. Although there were also cases where in some of the analyzed samples, the range and the concentration were within the WHO acceptable standard for drinking water. Most of the high concentrations in the analyzed groundwater are generally from anthropogenic sources and not natural or geological.

The following are hereby recommended as possible solutions to the groundwater quality problems in the study area:

i. that waters in such areas where the physic-chemical constituents are lower than the acceptable standards of the WHO are unsafe for human consumption and domestic use, and therefore should be treated to reduce or ameliorate the problems;

ii. that further work should be carried out to ascertain the specific anthropogenic contaminants in the analyzed waters so as to determine the level of contamination and be able to proffer appropriate remediation;

iii. that in areas where the cationic and anionic concentrations are far below the WHO acceptable levels, supplements should be advised to the residents of such areas or such be distributed so as to make up for the minimal intake recommended for domestic use by the World Health Organization;

iv. that further investigation of the entire area is necessary to determine the specific causes for the chemistry observed and to establish hypotheses on reasons for some of the abnormalities;

v. for the research approach, a larger number of samples should be taken to allow the optimization of a more routine study in the area; and,

vi. the startling statistics from this research work should, therefore, serve as a wake-up call for urgent remedial action from both the Local and State Governments, if the residents in these areas are to continually live healthily. They should be properly orientated on the need not to dump untreated/raw sewage into flowing surface waters and the environments so as to reduce the increasing rate of fecal contamination of both the surface and groundwater bodies from where majority of domestic water supply come from.

6. ACKNOWLEDGEMENT

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