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Physico-Chemical Investigation Of Groundwater Quality In Part Of Igarra, Edo State, Nigeria

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Abstract: *The physico-chemical investigation of groundwater quality in part of Igarra, Edo State, Nigeria, was conducted to determine the quality and potability of the groundwater in the study area. The study was carried out by the collection of twelve groundwater samples from hand-dug-wells for insitu and laboratory analysis water samples. The result of the physico-chemical properties of the water were compared with World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ, 2007) standards. The results shows that both the cations and anions in the groundwater falls into the permissible limits of WHO and NSDWQ, with the exception of HCO3 which exceeded the WHO and NSDWQ standards of 100 mg/l. The concentration sequence of cations in the groundwater has an order of Ca>Mg>Na>K, while the anions has an order of* HCO_3*>Cl>* NO_3*>*SO_4*>*NO_2*, with a Ca-*HCO_3 *water type. The study also shows that the pH of the groundwater has an average value of 6.82 ± 0.28, EC 423.75 ± 148.27 µS/cm, DO 2.94 ± 1.04 mg/l, COD 153.54 ± 21.31mg/l and BOD 1.13 ± 0.32 mg/l. The heavy metals concentration in the groundwater is high than their respective permissible limits of WHO and NSDWQ standards with the exception of Cu and Nickel which were below the permissible limits, in the order of Fe >Mn > Cu > Zn > Cr > Pb > Cd > Ni > V. This probably indicates that the geology and water-rock interaction is responsible for the high concentration of the heavy metals in the groundwater of the study area, and it poses serious health threat to the inhabitants. It is recommended that periodic assessment and low cost water treatment plant should be designed to improve the potability of the groundwater in the area.*

Keywords: *groundwater quality; physico-chemical; heavy metals; water-rock interaction; potability.*

I. INTRODUCTION

Water is an essential and precious resource upon which human, ecosystem, and agricultural production depend and is used for domestic, agriculture, power and industry purposes. Water quality monitoring has become imperative for maintaining its reliability for future use. There is an increasing awareness that water will be one of the most critical natural resources in future due to the fact that about 2 million children less than 5 five years die annually in developing countries as a result of water borne diseases (WHO, 2012).

Groundwater is the water present in the subsurface of the earth at the zone of saturation, and surface water are water found on the surface of the earth such as river, spring, lake and ocean. But surface is easily prone to anthropogenic activities and pollution as compared to groundwater. This activities results to higher concentrations of dissolved or suspended constituents of pollutant than the maximum admissible concentrations formulated by national or international standards (Amadi *et al.*, 2010). Thus, the quality of the water is significant to it uses. Water quality is the physical, chemical and biological attributes or characteristics of the water, this defines the suitability of the water for utility and consumption (Patil *et. al.*, 2012).

The increase in human population, industrialization, use of fertilizer and man-made activities water is highly polluted with harmful contaminants (Patil *et al*., 2012). Ocheri (2010) conducted research on the level of iron level in groundwater from boreholes and the spatial distribution across rural communities in Benue state, Nigeria, the results shows that 35% of the water analysed have high iron content according to World Health Organisation standard (WHO), the high iron content is as a result of the geology, rock-water interaction and agricultural activities in the study area. Aremu *et al.* (2011), conducted research on the physiochemical properties of groundwater from hand-dug wells, boreholes and stream water in Bwari and its environs. The result showed that all the parameters determined fall within the WHO, 2012 standard for drinking water quality, except for pH which are slightly acidic and four water types.

The World Health Organization reported that 80% of diseases afflicting man are water borne in developing countries which are directly connected with contaminated drinking water and this can cause endemic and epidemic gastrointestinal disease in the world (WHO 2004), this necessitated the physic-chemical investigation of groundwater quality in the study area.

II. THE STUDY AREA

The area can be accessed along the Auchi - Igarra - Ibilo expressway, Edo State, Nigeria. It lies on latitude $7^{o}17'06''$ to $7^{o}17'42.4''$ N and longitude $006^{o}06'11.3''$ to $006^{o}06'33.6''$ E of Igarra, Akoko Edo Local Government Area. Figure 1 shows the location of the study area.

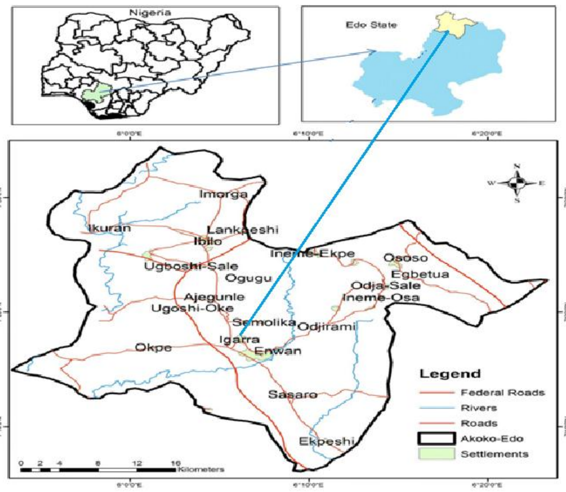

Figure 1: Location of the study area

The area has two principal seasons, which are the wet and dry seasons. The wet season starts in March and last till November with short break in August, while the dry season starts in November and ends in March. It is associated with hamattan that comes up between late November and February which is characterized by dusty winds as a result of the North East or trade wind (Matthew, 2002). The area is effectively drained by both surface and underground drainage system, and much of the drainage system is controlled structurally by faults and fractures.. Some of the streams have their source as springs; the tributaries join the main river channel which eventually flows into a river which is controlled by the River Niger.

The study area lies within the Guinea savannah vegetation belt characterized by short trees and tall grasses. The trees in this area are mostly concentrated along fracture zones within the plutonic bodies and on the Quartzite, ridges were adequate soil cover has resulted and there is adequate groundwater retention.

The study area is part of the basement complex of Nigeria, which is made up of older granites and metamorphic rocks. The study area falls within the South Western Crystalline Province of Nigeria, in the South western basement of Nigeria. Figure 2 shows the geology map of Nigeria (Obaje, 2009).

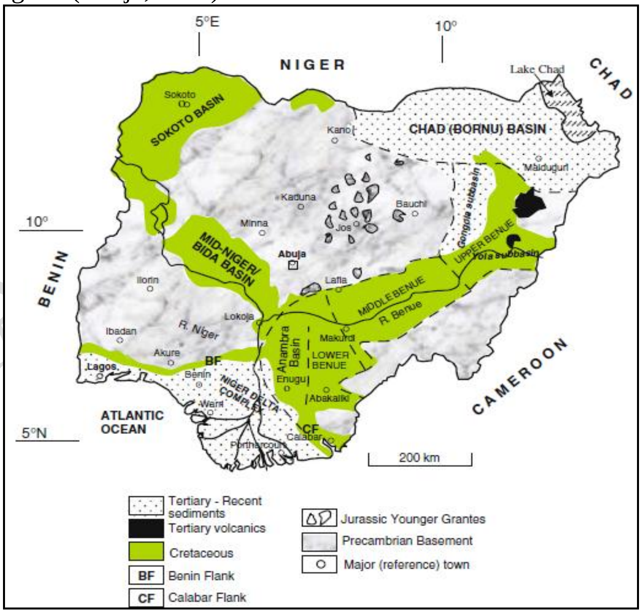

Figure 2: Geology map of Nigeria (Obaje, 2009)

III. HYDROGEOLOGY OF BASEMENT COMPLEX IN NIGERIA

The crystalline aquifers in this province are weathered and fractured rocks overlying the fresh basement rocks. Martins, (2001) further pointed out that across the eleven groundwater provinces in Nigeria two main aquifer types exist, which include the crystalline aquifer which covers about 50% of the country and the sedimentary aquifer, occupying the other half of the country.

IV. MATERIALS AND METHODS

The study is focused on determining the quality of the groundwater and surface water, and the presence of heavy metals in water. The materials used for the field investigation includes global positioning system (GPS), water sample

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containers and pH meter. The study was carried out in three stages which include desk studies, preliminary and detailed investigations. Groundwater samples were collected from twelve hand-dug-wells for insitu and laboratory analysis water samples. The results of the physico-chemical properties of the water samples were compared with WHO standard and Nigeria Standard for Drinking Water Quality (NSDWQ, 2007).

The pH meter was used to determine the physical property of the water samples in the field. The laboratory equipment used for water analysis includes Atomic Absorption Spectrophotometer (AAS) for the determination of Sodium, Potassium, Calcium, Magnesium and heavy metals which iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), Lead (Pb), vanadium (V), nickel (Ni), chromium (Cr) and cadmium (Cd). Spectronic 20D+ Spectrophotometer was used to determine the colour, turbidity, PO_4, SO_4, NO_3^-, NO_2, $NH4N^-$and total hydrocarbon content of the water sample, titration apparatus were used for determining the chemical parameters phosphorus (P), ammonium nitrogen (NH_4N), nitrate (NO_3), nitrite (NO_2), sulphate (SO_4), chloride (Cl), Dissolved Oxygen (DO), chemical oxygen demand (COD) and bicarbonate (HCO_3) in conjunction with the Spectronic 20D+ Spectrophotometer include, while oven and incubator were used to determined the biochemical oxygen demand (BOD) of the water.

V. RESULTS AND DISCUSSION

The statistical summary of the physico-chemical properties of the groundwater were shown in table 1.

Parameter	Unit	Mean	Standard deviation	Minimum value	Maximum value	WHO	NSDWQ (2007)
pH		6.82	0.28	6.4	7.4	**6.5-8.5**	**6.5-8.5**
Electrical conductivity (EC)	μS/cm	423.75	148.27	308.00	863.00	**1000**	**1000**
Total dissolved solids (TDS)	mg/l	172.84	60.45	43.10	262.00	**1000**	**500**
Dissolved Oxygen (DO)	mg/l	2.94	1.04	1.30	4.10	-	**100**
Biochemical Oxygen Demand (BOD)	mg/l	1.13	0.32	0.70	1.80	-	-
Chemical Oxygen Demand (COD)	mg/l	153.54	21.31	87.20	167.40	-	-
Sodium (Na)	mg/l	0.65	0.15	0.44	0.92	**200**	**200**
Potassium (K)	mg/l	0.14	0.05	0.06	0.22	-	-
Calcium (Ca)	mg/l	3.25	0.92	1.79	4.67	-	-
Magnesium (Mg)	mg/l	1.13	0.24	0.88	1.76	**50**	**20**
Bicarbonate (HCO_3)	mg/l	305.88	91.88	91.50	463.60	-	**100**
Chloride (Cl)	mg/l	103.38	29.49	88.60	194.90	**250**	**250**
Nitrite (NO_2)	mg/l	0.12	0.03	0.06	0.18	**0/2**	**0.2**
Nitrate (NO_3)	mg/l	1.41	0.41	0.69	1.99	**50**	**50**
Sulphate (SO_4)	mg/l	0.41	0.21	0.14	0.71	**100**	**100**
Phosphorus (P)	mg/l	0.32	0.09	0.18	0.46	-	-
NH_4-N	mg/l	0.19	0.03	0.14	0.25	-	-
Iron (Fe)	mg/l	1.533	0.315	1.12	2.11	**0/03**	**0.03**
Manganese (Mn)	mg/l	0.182	0.091	0.088	0.377	**0.2**	**0.2**
Copper (Cu)	mg/l	0.119	0.037	0.033	0.174	**1.0**	**1.0**
Zinc (Zn)	mg/l	0.679	0.289	0.128	1.075	**5.0**	**3.0**
Lead (Pb)	mg/l	0.0319	0.010	0.015	0.050	**0/05**	**0.01**
Cadmium (Cd)	mg/l	0.016	0.0083	0.006	0.0350	**0.003**	**0.003**
Chromium (Cr)	mg/l	0.073	0.0158	0.041	0.093	**0.05**	**0.05**
Nickel (Ni)	mg/l	0.0092	0.0049	0.004	0.0220	**0.02**	**0.02**
Vanadium (V)	mg/l	0.0063	0.0025	0.002	0.010	-	-

Table 1: statistical summary of physico-chemical properties of the groundwater

Figure 3 shows the plot of the physico-chemical properties and figure 4 the heavy metals of the groundwater.

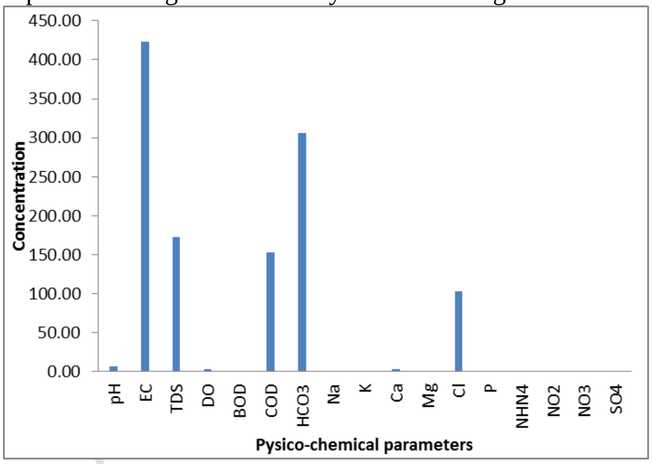

Figure 3: Plot of physico-chemical properties of the groundwater in the study area

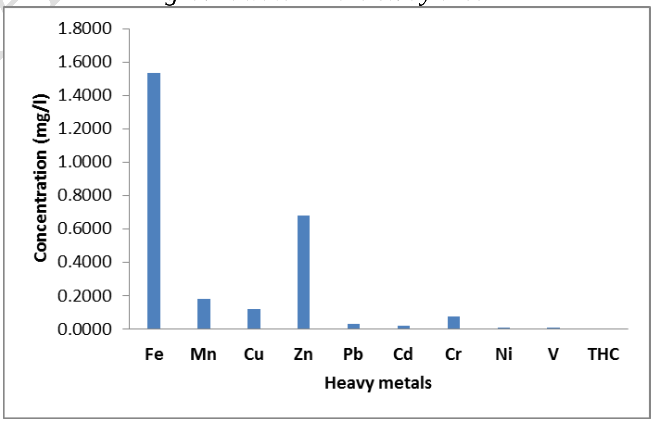

Figure 4: Plot of heavy metals of the groundwater in the study area

The heavy metals in the groundwater and some selected parameters were correlated as shown in table 2.

	pH	EC	TDS	DO	BOD	COD	Fe	Mn	Cu	Zn	Pb	Cd	Cr	Ni	V
pH	1														
EC	-0.04	1													
TDS	0.46	-0.45	1												
DO	-0.59	0.01	-0.28	1											
BOD	-0.46	-0.15	-0.55	0.68	1										
COD	-0.05	0.27	0.10	0.53	0.28	1									
Fe	-0.01	0.65	-0.08	-0.03	-0.21	0.40	1								
Mn	0.22	0.88	-0.09	-0.18	-0.32	0.35	0.60	1							
Cu	0.18	0.32	0.07	0.39	0.12	0.84	0.28	0.40	1						
Zn	-0.01	0.61	-0.24	0.35	0.26	0.66	0.52	0.63	0.73	1					
Pb	0.20	0.72	-0.38	0.17	0.26	0.56	0.56	0.68	0.62	0.89	1				
Cd	0.33	0.83	-0.28	-0.18	-0.17	0.32	0.55	0.86	0.38	0.47	0.70	1			
Cr	0.30	0.43	-0.31	0.34	0.37	0.69	0.32	0.40	0.75	0.67	0.82	0.58	1		
Ni	0.16	0.91	-0.39	-0.11	-0.15	0.29	0.66	0.90	0.31	0.53	0.71	0.96	0.52	1	
V	0.16	0.45	-0.35	0.12	0.29	0.37	0.58	0.39	0.18	0.30	0.59	0.63	0.66	0.65	1

Table 2: Correlation of some selected parameters of the groundwater in the study area

The pH of the groundwater has an average value of 6.82 ± 0.28, and it falls into the WHO and NSDWQ standards. DO of the groundwater has an average value of 2.94 ± 1.04 mg/l; chemical oxygen demand (COD) of the groundwater 153.54 ± 21.31mg/l. and the biochemical oxygen demand (BOD) of the groundwater has an average value of 1.13 ± 0.32 mg/l. The electrical conductivity (EC) of the groundwater has an average value of 423.75 ± 148.27 µS/cm, and it falls into the WHO and NSDWQ standards. The total dissolved solids (TDS) concentration of the groundwater has an average value of 172.84 ± 60.45, and it falls into the WHO and NSDWQ standards.

The cations concentration of the groundwater shows that sodium (Na) an average value of 0.65 ±0.15 mg/l, potassium (K) an average value of 0.14 ± 0.05 mg/l, calcium (Ca) an average value of 3.25 ± 0.92 mg/l and magnesium (Mg) an average value of 1.13 ± 0.24 mg/l and it falls into the WHO of 50 mg/l and NSDWQ standards of 20 mg/l. The concentration sequence of cations in the groundwater has an order of Ca>Mg>Na>K.

The anions concentration of the groundwater shows that chloride (Cl) has an average value of 103.38 ± 29.49 mg/l, and it falls into the WHO and NSDWQ standards of 250 mg/l. The nitrite (NO_2) concentration of the groundwater has an average value of 0.12 ± 0.03 mg/l, falls into the WHO and NSDWQ standards of 0.2 mg/l. The nitrate (NO_3) concentration of the groundwater has an average value of 1.41 ± 0.41 mg/l, falls into the WHO and NSDWQ standards of 50 mg/l. The sulphide (SO_4) concentration of the groundwater has an average value of 0.41 ± 0.21 mg/l, falls into the WHO and NSDWQ standards of 100 mg/l. The bicarbonate (HCO_3) concentration of the groundwater has an average value of 305.88 ± 91.88 mg/l. The value of HCO_3 water exceeded the WHO and NSDWQ standards of 100 mg/l. The concentration sequence of anions in the water has an order of HCO_3>Cl> NO_3>SO_4>NO_2. Variants of general water type are due to major differences in the composition of the aquifer rock (Kevin, 2005), and the groundwater typical contains Ca and HCO_3 composition as it major cation and anion respectively, indicating Ca-HCO_3 water type.

The heavy metals concentration in the groundwater has an iron (Fe) average value of 1.533 ± 0.315 mg/l. The concentration of Fe in the water exceeded the WHO and NSDWQ standards of 0.3 mg/l. The manganese (Mn) concentration in the groundwater has an average value of 0.182 ± 0.091 mg/l, with a minimum value of 0.088 mg/l and a maximum value of 0.377 mg/l. This shows that the maximum value of Mn 0.377 mg/l of the groundwater in the study area exceeded the WHO and NSDWQ standards of 0.2 mg/l. The lead (Pb) concentration in the groundwater has an average value of 0.0319 ± 0.01 mg/l. The value of Pb in the groundwater in the study area exceeded the NSDWQ standards of 0.01 mg/l. The chromium (Cr) concentration in the groundwater has an average value of 0.073 ± 0.0158 mg/l. The value of Cr in the groundwater in the study area exceeded the WHO and NSDWQ standards of 0.05 mg/l. The copper (Cu) concentration in the groundwater has an average value of 0.119 ± 0.037 mg/l, and it falls into the WHO and NSDWQ standards of 1.0 mg/l. The cadmium (Cd) concentration in the groundwater has an average value of 0.016 ± 0.0083 mg/l. The value of Cd in the groundwater in the study area exceeded the NSDWQ standards of 0.003 mg/l. The nickel (Ni) concentration in the groundwater has an average value of 0.0092 ± 0.0049 mg/l, and it falls into the WHO and NSDWQ standards of 0.02 mg/l. The vanidium (V) concentration in the groundwater has an average value of 0.0063 ± 0.0025 mg/l. The concentration sequence of the heavy metals is in the order of Fe >Mn > Cu > Zn > Cr > Pb > Cd > Ni > V.

The correlation of some parameter and heavy metals in the groundwater of the study area revealed that the pH has a positive correlation with the heavy metals with the exception of Fe and Zn which is a negative correlation. The pH also has a negative correlation with EC, DO, BOD and COD, with a positive correlation with TDS. This indicates that as the pH increases the heavy metals increases, while as the pH decreases the concentration of Fe and Zn increases. This probably indicates that the geology and water-rock interaction is responsible for the high concentration of the heavy metals in the groundwater of the study area.

VI. CONCLUSION AND RECOMMENDATIONS

Groundwater is the water present in the subsurface of the earth at the zone of saturation and it is not easily prone to anthropogenic activities and pollution as compared to groundwater. The quality of the groundwater is significant to it uses and this study investigates the quality of groundwater in part of Igarra, Edo State. The study shows that the pH of the groundwater has an average value of 6.82 ± 0.28, EC 423.75 ± 148.27 µS/cm, DO 2.94 ± 1.04 mg/l, COD 153.54 ± 21.31 mg/l and BOD 1.13 ± 0.32 mg/l. The concentration sequence of cations in the groundwater has an order of Ca>Mg>Na>K, while the concentration sequence of anions in the water has an order of HCO_3>Cl>NO_3>SO_4>NO_2. The groundwater typical contains Ca and HCO_3 composition as it major cation and anion respectively, indicating Ca-HCO_3 water type.

The heavy metals concentration in the groundwater is high than their respective permissible limits of WHO and NSDWQ standards with the exception of Cu and Nickel which were below the permissible limits. Fe has a concentration of 1.533 ± 0.315 mg/l, Mn 0.182 ± 0.091 mg/l, Pb 0.0319 ± 0.01 mg/l, Cr 0.073 ± 0.0158 mg/l, Cu 0.119 ± 0.037 mg/l, Cd 0.016 ± 0.0083 mg/l, Ni 0.0092 ± 0.0049 mg/l and V 0.0063 ± 0.0025 mg/l. The concentration sequence of the heavy metals is in the order of Fe >Mn > Cu > Zn > Cr > Pb > Cd > Ni > V.

The correlation of some parameter and heavy metals in the groundwater of the study area indicates that as the pH increases the heavy metals increases, while as the pH decreases the concentration of Fe and Zn increases. This probably indicates that the geology and water-rock interaction is responsible for the high concentration of the heavy metals in the groundwater of the study area. The presence of high heavy metals in the groundwater in the study poses serious health threat and challenges to the inhabitants in the community.

It is recommended that periodic assessment of the groundwater quality in the study area should be carried out and low cost water treatment plant should be designed to improve the potability of the groundwater in the area. Also sensitization exercise on the health challenges relating to high concentration of heavy metals in the groundwater should be carried out in the study area, and detailed studies should be carried out to determine the risk assessment of heavy metals in the groundwater.

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