Hydrochemical Evaluation of Groundwater Resources in Ngbo Areas, Ebonyi State, Southeast Nigeria.

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ABSTRACT

The hydrochemical evaluation of groundwater resources of Ngbo Area have been carried out covering parts of Ohaukwu and Ebonyi LGAs of Ebonyi State. The area lies between latitudes 6025'N and 6030'N, and longitudes 8000'E and 8005'E. Geologically, the area is underlain by highly consolidated dark-grey and fissile- brown shales, limestone and mudstones belonging to the Albian Asu River Group. Ten (10) groundwater samples were collected for analysis using Standard sampling procedures. The result which was compared with the World Health Organization and Nigerian Standard shows that the mean concentration of the physical parameters such as pH (6.92), total dissolved solid (15.56), electrical conductivity (15.56), and total hardness (1.0mg/l) of the groundwater of the area are fresh (due to TDS < 1000 mg/l at temperature range of 270C to 300C), dominantly alkaline, moderately hard in some locations such as locations 7 (Umuezaka Ngbo), 9 (Hill Top Pri. Sch., Amoffia Ngbo) and 10 (Ndiulo Umusoke Amoffia Ngbo), possibly due to bicarbonate (HCO3–) concentrations of 340mg/l, 279mg/l, and 335mg/l, and were within the permissible limits for drinking, domestic, industrial and agricultural purposes. High concentration of chloride ions in some of the samples was indicated. This could be attributed to the presence of igneous rocks and the leaching of sewage effluents down to the groundwater system. The dominant order of cations and anions chemistry for most of the analyzed groundwater samples is Ca2+>Mg2+>Na+>K+ and Cl–>HCO3– >SO42-> and NO3– respectively. This is a reflection of high carbonates in the rocks. Proper sewage disposal should be upheld in the area.

Keywords: Groundwater; Limestone; Carbonates; Hydrochemical; Cations; Anions.

INTRODUCTION

Groundwater is one of the most precious natural resources on the planet, and its relevance in sustaining healthy populations in society is driving up demand (Obasi and Akudinobi, 2020; Igwe, et al., 2017; Obiorah, et al., 2018). On a global basis, groundwater is regarded critical in the development of industrial estates, tourist hubs, urban and agricultural populations (Niu et al., 2017, Xaincang, et al., (2020); Laxaman. et al., (2021); Azadeh, et al., (2020). The importance of groundwater in the conservation of global food security has been highlighted (Wada et al., 2014 and Obasi et al., 2021). Groundwater plays an important role in both private and public water supplies all over the world, most especially in the social and economic life of the people in terms of domestic, industrial, religious and agricultural use (Pradhan and Pirasteh, 2011; Ibeh and Okplenye, 2005). It is controlled by geology, including tectonic activities. However, depending on the intended goal, the level and quality of available water resources might become a worldwide concern, limiting a region's long-term development and ecological balance (Azada, et al., 2020). Eyankware et al., 2018b has emphasized that groundwater is preferred to surface water because it is readily free from surface contamination, and it is also considered to be less prone to contamination when compared to surface. Further, in most scenarios, groundwater is contaminated by infiltration from surface pollution such as leakage from septic tanks, mining activities, and indiscriminate waste disposal, among others. Niu et al., (2017) and Xaincang, et al.,(2020) noted that several factors are responsible for the alteration of groundwater resource.

Hydrochemical evaluation of water resources is pertinent to acertain the chemical, physical and biological composition of water. This is very necessary as the composition of water determines its domestic, industrial or agricultural uses. Many authors, including Okolo et al., (2018); Obasi., et al (2021, 2022); Obasi (2020); Moye et al (2017), Rubio et al, (2000); Nieto et al, (2007) Eyankware et al, (2016, 2018a,) have used different approach to evaluate surface and groundwater resources in different parts of the Africa and Nigeria. The study area, Ngbo is located in the outskirt of Abakaliki. It lies between latitudes $6^0$25'N and 6^0 30'N, and longitudes $8^0$00'E and $8^0$05'E. The area covers seven communities in parts of Ohaukwu and Ebonyi Local Government Areas of Ebonyi State. The entire area is geologically characterized by the occurrence of hard carbonaceous shales and limestone which has effects on the water quality of the area. Also, the shales and limestone has made the area an economic hub for mining and quarrying activities. This have led to continuous excavations, uncontrolled dumping of mine/quarry dust/wastes frequent discharge of mine and quarry wastewaters into agricultural farmlands and stream channels. All these introduce heavy metals into the environment and can find their way into groundwater sources. It is therefore, against this background that the hydrochemical evaluation of groundwater in Ngbo is necessary. The assessment of the quality of groundwater with respect to basic constituents and heavy metals in Ngbo area has been carried out. This work has established the distribution patterns of major and minor constituents and heavy metals especially, Cr, Mn, As, Ag, V, Pb, Zn, Cu, Cd, Ni and Co in water in the area.. Emphasis will be made in determining the physiochemical parameters of the samples in-situ alongside the processes responsible for the water chemistry bearing in mind natural and anthropogenic inputs. Turbidity, total dissolve solid (TDS), potential of Hydrogen (pH) and Electrical conductivity (EC) of the study area has been evaluated.

GEOLOGY AND PHYSIOGRAPHY

The Ngbo Area lies within the Lower Benue Trough (Fig. 2). The Trough is believed to be formed by the opening of the South Atlantic (Gulf of Guinea) during the Lower Cretaceous time of the continental separation between Africa and South America. Marine incursion into the Benue Trough led to the sedimentation within the Southern Nigerian sedimentary basin (Cratchley and Jones; 1965, Nwachukwu; 1972, Olade, 1975). Benue Trough of Nigeria (Fig. 3) has been studied and described in various publications of Geological Survey of Nigeria (GSN) and variously by Reyment (1965), Kogbe (1976), Benkhelil (1987) and others. It comprises of Abakaliki Anticlinorum, the Afikpo Syncline to the East and Anambra Basin to the West.

However, most research work in Abakaliki area has been incorporated into regional investigation including those by Awalla and Ezeigbo, (2002); Obasi (2020), Tijani, (2003); Murat, (1972); Ofoegbu and Onuoha, (1991). Their works were based on the regional geology of the area. Moreover, the discoveries of limestone, lead-zinc and other heavy metals including the search for secondary porosity for groundwater has attracted more interest in the detailed geological study of parts of the area. Recent workers like Onwe et al., (2022) investigated the concentrations of hydrochemical attributes of water resources in some parts of Ngbo and observed high concentrations of nitrate, sulphates and some heavy metals. All these emanates from toxic wastes. In all cases, none of these workers have assessed the soil-water interaction (hydrochemistry) of Ngbo Area at a particular time or season. They have not assessed the entire mining fields in other to

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compare the concentration and degree of pollution or contamination which is necessary for determining the groundwater use in the area.

Ngbo Area is however underlain by the Asu River Group, which is a product of the earliest documented marine transgression in Nigeria (Nwajide, 2013). This marine transgression occurred during the middle Albian and was limited to the Benue valley and Southeastern Nigeria where the Asu River Group sediments as well as the Abakaliki Shales were deposited in moderately deep marine waters (Kogbe, 1976). The Asu River Group consists largely of olive-brown sandy shales, fine grained micaceouse sandstones, micaceous mudstones. Bluish-grey or olive-brown shales which weather to a rusty brown colour are also present. The sequence is poorly fossiliferous, though there are occasional outcrops of limestone. The beds are exposed at Akpegu Amoffia Ngbo, abandoned SGEEN and Macdaniel's Quarry sites in Amoffia Ngbo, Seaman Mining and Construction Ltd., Umuezaka Ngbo. Paleontologically, the Albian is mainly characterized by species of Mortoniceras and Eloiceras. It is also rich in ammonites as well as foraminifera, radiolarian and pollens (Reyment, 1965). Reyment (1965) stated that the geology of the study area is a time equivalent of the Uomba Formation, the Arufu and Gboko (Yandev) limestone in the middle Benue sub-basin. This could be correlated with Bima sandstone in the upper Benue Trough (Fig. 3). Structurally, the sediments are folded, particularly in the Southern area of Abakaliki; the fold axis stretch NE-SW (Nwajide, 2013). This is supported by Olade (1975), who showed that the area lies within the Southeastern limb of an asymmetrical anticline with NE-SW axis.

METHODOLOGY

Water Sample Collection

Ten (10) water samples were systematically collected from groundwater sources from boreholes and hand dug wells (fig 1). Each sample was collected using pre- washed one (1) liter plastic water bottle which was thoroughly rinsed with same sample water in order to avoid contamination from the container. The coordinates and elevations of the sample location were recorded using GPS. The samples were labeled properly with the location names, and were conveyed to the Hydrochemistry laboratory at the same day of collection. Total of sixteen parameters were analyzed from the water samples. Physical parameters such as pH, Conductivity, Turbidity, Total Dissolved Solid and heavy metals which include lead, copper, vanadium, cadmium, chromium, selenium, zinc, manganese, silver, cobalt, and Arsenic.

Laboratory/ Water Analysis

The above elements were chosen because they are environmentally sensitive and their depletion or concentration in the environment, especially in the river and groundwater systems affects the development and health of plants, animals, and humans. This is more important when these parameters enter into the food chain. However, their analytical procedure was according to the World Health Organization (WHO, 2004) as follows: Electrical conductivity and pH of the water samples were measured by electrometric method, using laboratory pH meter [according to American Public Health Association, (APHA) 2510B guidelines Model DDS-307(APHA; 1998)] and conductivity cell [according to American Public Health Association, (APHA) 2510 B guideline Model DDS-307(APHA; 1998)]. The heavy metal analysis was done using Varian AA240 Atomic Absorption Spectrometer (AAS) according to APHA, 1995 guidelines. Total Dissolved Solids (TDS) was determined using APHA2510A TDS 139 tester (APHA; 1998). Alkalinity was determined titrimetrically with standard solution of hydrochloric acid (HCl). Alkalinity was calculated as Alkalinity (HCO_3) [mg/l $CaCO_3$] = Volume of 0.1N HCl acid used (ml) x 50,000/ml of water sample.

Nitrate was determined using the HACH DR/2010 spectrophotometer by the principle of the cadmium reduction method. The instrument was zeroed with a fresh sample and the nitrate measured at a wavelength

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of 500nm while placing the treated sample in the sample holder. Sulphate was determined using the HACH DR/2010 spectrophotometer by the principle of turbidimetry. The instrument was zeroed with a fresh sample and the sulphate measured at a wavelength of 450nm while placing the treated sample in the sample holder. Calcium and Magnesium were determined from the water samples using the Bulk Scientific Atomic Absorption Spectrophotometer (AAS), 200A Series model while Potassium and Sodium were determined with the aid of flame photometer.

RESULTS AND DISCUSSION

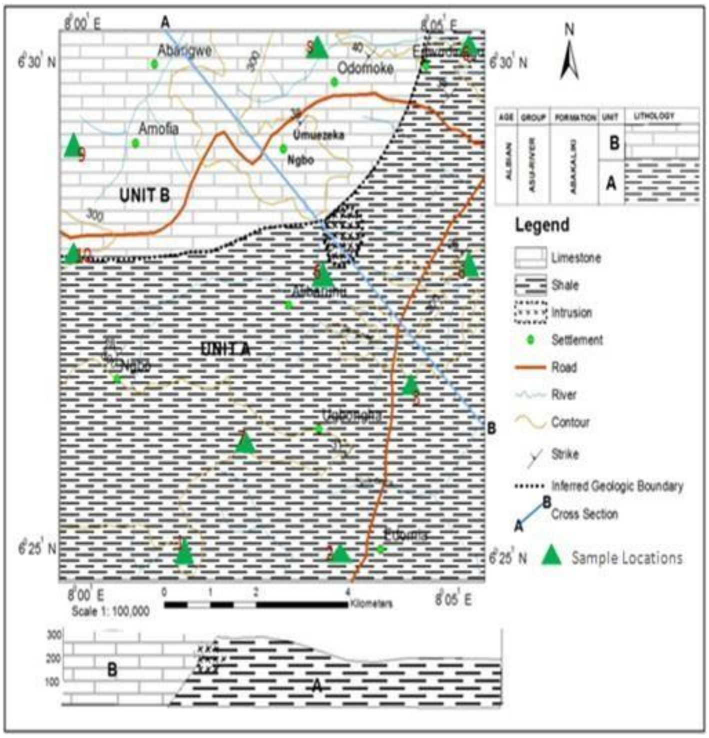

Figure 1: Geologic Map of the Study Area with water sample collection points.

Hydrochemical Analysis of Groundwater in the Study Area

The results of the hydrochemical analysis are presented in Table 1, which was compared with standards for drinking water. The parameters were within the acceptable limits, and present the water samples as portable, though in locations 5 and 8 (Umuezaka Ngbo and Hill Top Primary School) the chloride and sulphates are relatively high possibly due to igneous intrusion in those areas.

Table 1: Result of the groundwater samples analysis as it is obtained from the laboratory of Springboard Research, Awka.

Parameters with Coordinates and Elevation	1	2	3	4	5	6	7	8	9	10
	008^{0} 02'E	008^{0} 03'E	008^{0} 04'E	008^{0} 05'E	008^{0} 05'E	008^{0} 03'E	008^{0} 02'E	008^{0} 03'E	008^{0} 00'E	008^{0} 058'E
	06^{0} 24'N	06^{0} 25'N	06^{0} 27'N	06^{0}28'N	06^{0} 30'N	06^{0} 28'N	06^{0}27'N	06^{0} 30'N	06^{0} 29'N	06^{0} 28'N
	66m	83m	74m	39m	75m	80m	71m	75m	85m	105m

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pH	**6.52**	7.28	8.01	7.80	5.32	4.99	6.92	8.41	7.51	6.39
EC (µS/cm).	**18.25**	11.40	10.22	19.80	12.12	19.48	11.69	15.42	17.88	19.29
TDS	**1.24**	0.76	0.85	1.84	1.83	1.06	0.42	0.53	0.44	1.02
Total Hardness (mg/l)	12.88	29.28	21.28	84.82	18.14	13.66	105.49	48.10	79.91	94.34
Calcium (mg/l)	5.42	23.42	19.65	76.40	11.48	4.67	98.01	42.91	69.42	82.49
Magnesium (mg/l)	7.46	5.86	1.63	8.42	6.60	8.9s9	7.48	5.19	10.49	11.85
Sodium (mg/l)	0.94	1.18	0.11	2.67	3.09	2.84	8.02	8.16	10.25	6.48
Potassium (mg/l)	1.33	1.39	0.14	2.81	0.96	1.48	6.44	5.91	4.88	6.00
Carbonate (mg/l)	72	98	28	196	201	106	280	111	260	291
Hydrogen Carbonate (mg/l)	41	109	31	218	45	179	340	228	279	335
Sulphate (mg/l)	8.11	6.46	20.45	174.22	208	196.8	30.40	79.88	26.10	18.25
Chloride (mg/l)	102	121	110	152	302	117	146	288	146	200
Nitrate (mg/l)	10.62	4.26	1.48	9.86	2.46	6.82	1.78	2.89	3.44	4.87
Cadmium (mg/l)	0.00	0.00	0.03	0.99	0.09	0.06	0.00	0.00	0.00	0.00
Lead (mg/l)	0.00	0.00	0.09	0.63	0.65	0.80	0.06	1.27	0.00	0.06
Chromium (mg/l)	0.00	0.03	0.00	0.04	0.81	0.00	0.01	0.12	0.00	0.00
Mercury (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arsenic (mg/l)	0.00	0.00	0.00	0.27	0.82	0.12	0.41	0.00	0.65	0.58
Silver (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manganese (mg/l)	0.54	0.08	0.12	0.82	2.47	1.81	0.09	0.95	0.78	0.64
Zinc (mg/l)	0.00	0.00	0.00	0.20	0.31	0.57	0.00	0.00	0.01	0.00

Table 2: Descriptive statistics of analyzed groundwater samples compared with WHO Standards for Drinking Water Quality

Parameters	Minimum	Maximum	Mean	WHO (2011)
pH	4.99	8.41	6.92	6.5-8.5
EC (µS/cm)	10.22	19.80	15.56	50
TDS	0.42	1.24	1.0	500
Total Hardness (mg/l)	12.88	105.49	50.79	500
Ca^{2+} (mg/l)	4.67	98.01	43.39	75
Mg^{2+} (mg/l)	1.63	11.85	7.40	50
Na^{+} (mg/l)	0.11	10.25	4.37	200
K^{+} **(mg/l)**	0.14	6.00	3.13	30
CO_3^{-} (mg/l)	28	291	164.30	250
HCO_3^{-} (mg/l)	31	335	150.35	380
SO_4^{2-} **(mg/l)**	6.46	208	76.87	500
Cl^{-} (mg/l)	102	302	168.40	250
NO_3^{-} (mg/l)	1.48	10.62	4.85	10
Cd (mg/l)	0.00	0.99	0.12	0.05
Pb (mg/l)	0.00	1.27	0.36	0.01
Cr (mg/l)	0.00	0.81	0.10	0.05

Hg (mg/l)	0.00	0.00	0.00	0.05
As (mg/l)	0.00	0.82	0.29	–
Ag (mg/l)	0.00	0.00	0.00	–
Mn (mg/l)	0.08	2.47	0.83	0.1
Zn(mg/l)	0.00	0.57	0.11	3.00

Discussions

Hydrochemical Analysis of Groundwater in the Study Area

For the purpose of simplicity and clarity, the parameters analyzed are divided into physical, chemical and trace/minor constituents. However, the concentration of dissolved chemical constituents in water according to Freeze and Cherry (1979) has been divided into major, minor and trace elements. Todd (1980) used major, secondary, minor and trace constituents in his classification.

Physical Parameters

Physical parameters are any parameter that is measurable; whose value describes state of a physical system. The changes of this physical parameter of a system can be used to describe its transformations or evolution between its momentary states. The parameters analyzed on the course of this work includes; Hydrogen concentration (pH), Total Dissolved Solid (TDS), Total Hardness and Electrical Conductivity (EC).

pH

This measures hydrogen ion concentration in water. It controls the major activities that take place in any environment. Pure water has a pH very close to 7 at 25C. Solution with a pH less than 7 are said to be acidic while solutions with a pH greater than 7 are basic or alkaline (WHO, 2011). The pH of the groundwater in the study area ranges from 4.99 – 8.41 (Table 2). The mean value is 6.92mg/l. All samples except three (3) shows pH values above 6.5mg/l thus, indicating minor variability in pH. The groundwater in the area will therefore be described as being dominantly alkaline and falling within 6.5 to 8.5 pH range of the World Health Organization (WHO, 2011) for water quality standards. However, the sample locations that have lower pH values may be due to the influence of carbonic acid at the near surface because of high CO_2^- dissolution in the area.

Electrical Conductivity (μS/cm).

This is the reciprocal of electrical resistivity, and measures a material's ability to conduct an electric current. The ability of water to conduct electric current is due to the presence of solids in solution which is referred to as total dissolved solid. The conductivity of the groundwater samples analyzed ranges from 10.22 -19.80 μS/cm. The mean value is 15.56 μS/cm. This means that the groundwater in the study area has a very low electrical conductivity when compared with the WHO standard (See Table 2).

Total Dissolved Solid (TDS).

This is the measure of the combined content of all inorganic and organic substances contained in a liquid in; molecular, ionized or micro-granular suspended form. The chemical may be cations, anions, molecular or agglomeration on the order of one thousand or fewer molecules, so long as a soluble micro-granule is formed. In the study area, the concentration of total dissolved solid ranges from 0.42 – 1.84mg/l. The mean value is 0.99mg/l. This shows that the TDS in the groundwater of the study area is within the range according to the WHO standard of 5mg/l (See table 2). This means that the groundwater of the study area is safe for drinking. Hence, the groundwater can be classified as fresh groundwater since the range is within

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the WHO standard (WHO, 2004).

Chemical Parameters

This has to do with the concentration of dissolved chemical constituents in water. It could be of organic or inorganic origin. The chemical parameters have been grouped into major cations and anions for easy understanding.

Major Cations

The following are the concentration of the major cations in groundwater samples analyzed. They includes; magnesium ion ($Mg^{2+)}$ calcium (Ca^{2+}), sodium (Na^+), and potassium (K^+).

Magnesium (Mg^{2+})

This is very common in natural water, and has always been associated with water hardness. In the study area, Mg^{2+} is sourced from weathering of rocks containing ferromagnesian mineral and from carbonate rocks. The analysis revealed that the magnesium ion concentration in the groundwater samples ranges from 1.63 – 11.85mg/l. WHO standard indicate that the permissible limit is 50mg/l. This indicates that the groundwater is safe for drinking.

Calcium Ion (Ca^{2+})

This is commonly present in natural waters often resulting from the dissolution of calcium rich rocks. The salts of calcium and magnesium are the result of groundwater (borehole) hardness, including the industrial waste effluents in host rocks, especially shally and clayey deposits and acid rains. The water sample analyzed within the study areas has calcium concentration within the range of 4.67 – 98.01mg/l (see Fig. 2). According to Drever (1982), calcium concentration in natural waters are typically less than 15mg/l, but water associated with carbonate rocks may have concentrations between 30mg/l and 100mg/l. WHO recommends 75mg/l of Ca^{2+} permissible. Therefore, the calcium ion concentration in the groundwater of the samples analyzed is permissible in accordance with the WHO standard.

Sodium (Na^+) and Potassium (K^+).

Sodium (Na^+) and Potassium (K^+) are present in natural water in high concentration, and may be introduced to the environment as sewages, industrial effluents, agricultural fertilizers and their farm inputs. Na^+ and K^+ enter into natural water through leaching. Sodium and potassium ions carbonate in recirculation cooling water can cause deterioration of wood in cooling towers. High concentration can cause problem in ice manufacture (Todd, 1980). The concentration of Na^+ and K^+ in the groundwater of the study area ranges from 0.11 -10.25mg/l and 0.14 – 6.44mg/l respectively which are permissible according to the WHO (2011) standard thus, good for drinking (See Table 2 and Figure 2)

The mean concentration of the total hardness is 50.79 mg/l (Table 2) which falls below 75mg/l and 150 mg/l acceptable range of water hardness prescription according to WHO; 2011. The result shows that the hardness of the groundwater of the area is generally moderate. From the table above, it is also worthy of note that all the groundwater samples are contaminated with nitrate (NO_3^-) (concentrations less than 50mg/l).

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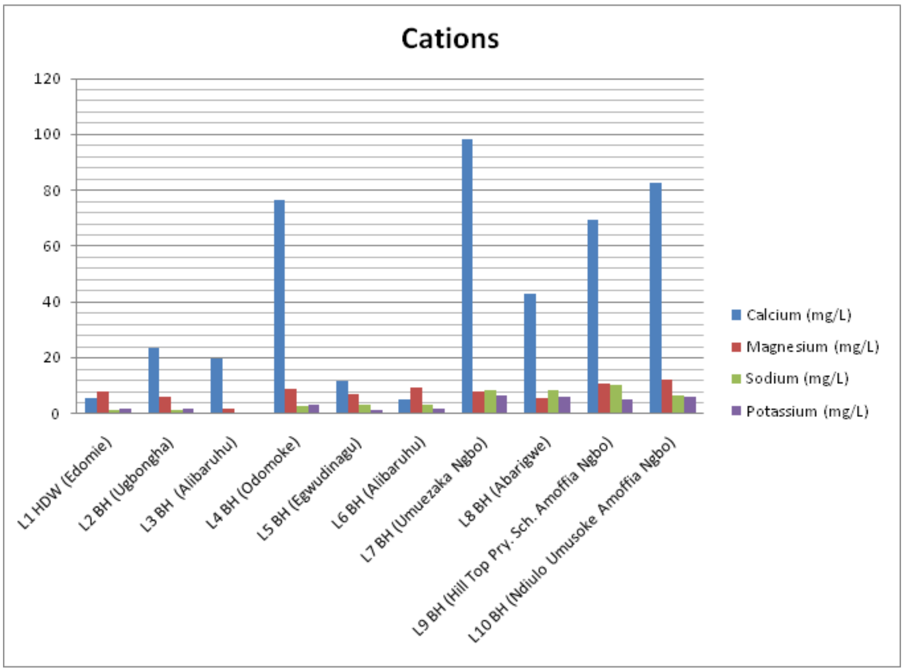

Figure 2: Concentration of various Cations in the Groundwater Samples Analyzed

Major Anions

The following are the appreciable concentration of major anions in groundwater samples analyzed; chloride ion (Cl^-), sulphate ion (SO_4^{2-}) and nitrate (NO_3^-) ion respectively**.**

Chloride Ions (Cl^-)

The chloride ions in natural water are dissolution of sedimentary rocks especially the evaporites, like gypsum and halite, agricultural impacts, sewage and industrial wastes. Chloride ions (Cl^-) is commonly less than 10mg/l in humid regions, but up to 1000mg/l in more arid regions. Chloride concentration in the study area ranges from 102 – 302mg/l. According to WHO (2011), the permissible concentration of chloride for good source of water supply is 250mg/l. It can be inferred that the concentration of chlorine is high at location 5 (Egwudinagu), location 8 (Abarigwe) and location 10 (Ndiulo Umusoke Amoffia) respectively. The high chloride concentrations may be attributed to the leaching of sewage effluents down to the groundwater system in the highly populated areas (Location 5 (Egwudinagu), location 8 (Abarigwe) and location 10 (Ndiulo Umusoke Amoffia) where indiscriminate disposal of sewage is suspected to be responsible for the pollution of groundwater by sewage effluent. It could also be as a result of diorite intrusion at Alibaruhu (Location 6). Excess of chloride in an area can cause salty taste and can result in physiological damage (Todd, 1980). According to Hems, (1989)**,** high concentration above 250mg/l is corrosive to pipes.

Nitrates (NO_3^-)

Nitrate is an important natural constituent of water. High concentration may indicate sources of past or present pollution. Its major sources in water are through organic matter from man-made pollutants such as agricultural fertilizers, urban effluents, solid waste disposal and livestock sewage.

The WHO permissible limit is 50mg/l and higher concentration has been known to cause cyanosis and Asphyxia in infants less than three (3) months (WHO, 2011). In the study area, nitrates (NO_3^-) concentration ranges from 1.48 – 10.62mg/l. It is within the WHO standard. This means that the source of water supply is safe for drinking. This also indicates there is no past or present polluting from urban waste in the area.

Sulphate (SO_4^{2-})

Sulphate ions are naturally present in groundwater. They are mostly occurring as a result of the oxidation of sulphide ores, gypsum and anhydrites. They can as well occur as leachates from their ores and other minerals. $SO4^{2-}$ is commonly less than 300mg/l in natural water, except in well influenced by acid mines (Todd, 1980). The sulphate concentration that is less than 400mg/l makes drinking water becomes unpleasant according to Pipkin (1994). Any concentration greater than 500mg/l will have bitter taste in water (Todd, 1980). In the study area, the concentration of sulphate ion in groundwater ranges from 6.46 – 208mg/l. This is within the WHO standard for drinking water (See table 2 and Figure 3 below).

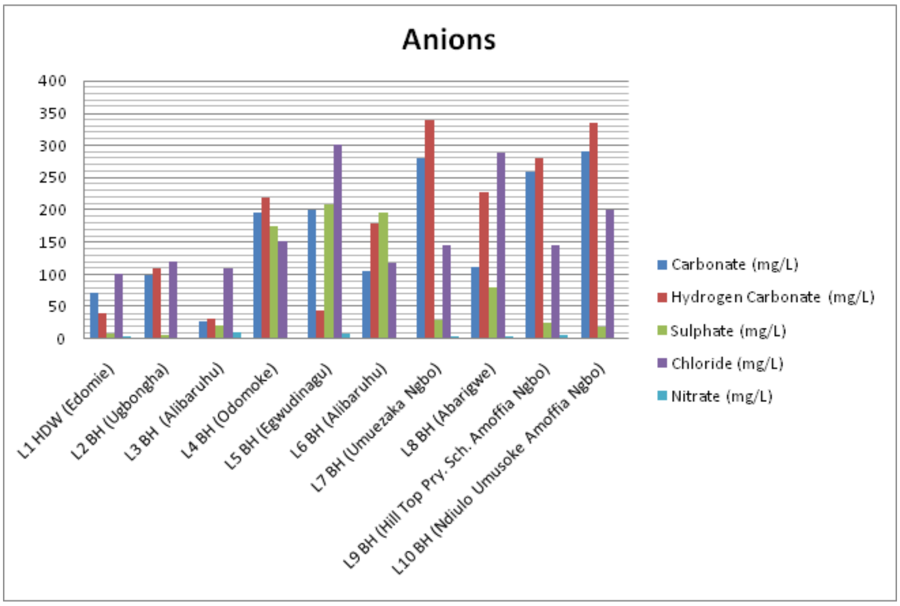

Figure 3: Concentration of Various Anions in the Groundwater Samples Analyzed.

Heavy Metals

Heavy metals are elements that have a relatively high density and toxic at lower concentrations. Heavy metals are those metals that are detrimental, harmful to man, plants and animals. These metals disturb the normal biological or biochemical processes in living organisms. They are metallic elements with specific gravity greater than five (5), such as cadmium, copper, lead, zinc, mercury, manganese, chromium and arsenic. A feature that heavy metals have in common is that, they tend to accumulate in the bodies of organism that ingest them. Therefore, their concentrations increase up the food chain. For instance, some marine algae may contain heavy metal at concentration up to one hundred times that of the water in which they are living. Small fish eating the algae develop higher concentrations of heavy metals in their flesh; larger fishes who eat the smaller fishes concentrate the metals still further and so on up to fish eating birds or mammals. Very few people seem to realize that metals lost to our environment pose human health problems. Japanese itri-itri disease was traced to the consumption of rice grown in cadmium contaminated irrigation water, while brain damage and incidence of lung cancer have been attributed to lead and nickel contamination respectively. The liver, the kidney, respiratory and reproductive systems are mostly affected by heavy metals.

The health effects of heavy metals can be either acute or chronic. Acute effect; usually follows a large dose of a chemical and occurs almost immediately. Examples are nausea, lung irritation, skin rash, vomiting, dizziness and in the extreme, death.

Chronic Effect

These are effects that occur after exposure to small amounts of a chemical over a long period. Examples include cancer, birth defects, organ damage, disorders of the nervous system and damage to the immune system. Some of the heavy metals commonly found to be toxic include cadmium, chromium copper, lead, mercury, nickel, etc. In the study area, the concentration of heavy metals in the groundwater of the samples analyzed ranges from lead manganese 0.08 – 1.81mg/l, chromium 0.00 – 0.81mg/l and arsenic 0.00 – 0.82mg/l respectively (See table 3 and Figure 4 below). The relative abundance of the trace metals arranged in increasing order of magnitude is as follows: Mn > Pb > Cd > As > Zn > Ag > Hg. 0.00 – 1.27mg/l, zinc 0.00 – 0.57mg/l, mercury 0.00 – 0.00, cadmium 0.00 – 0.99mg/l,

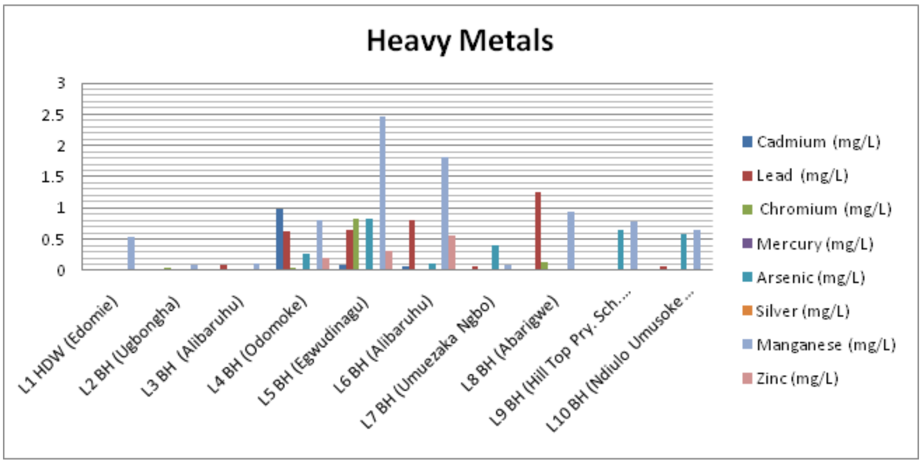

Figure 4: Concentration of Various Heavy Metals in the Groundwater Samples Analyzed.

Table 3: Sources and Health Effects of some Heavy Metals

Metals	**Sources**	**Effects**
Cadmium (Cd)	Coal, petroleum, mining and smelting operations, fossil fuel combustion, sewage sludge disposal, fertilizer application, paint pigments etc	Kidney dysfunction, hypertension, anaemia, lever damage, vomiting carcinogenic, diarrhea muscle cramps, nausea
Lead (Pb)	Volcanic eruptions, sea salt sprays, forest fires, mining and smelting operation, leaded gasoline, batteries.	Enzyme inhibition, kidney impairment, neurological disorders, teratogenic effect, birth defects
Mercury (Hg)	Coal, mining and smelting operations fossil fuel combustion, electrical appliances, insecticides, fungicides pharmaceuticals	Kidney malfunction, renal effect, teratogenic effect, neurological disorders, enzyme inhibition, carcinogenic
Manganese (Mn)	Occurs mostly with Fe deposits	Causes gastrointestinal disturbances

CONCLUSION

Geology and hydrochemical analysis of groundwater of Ngbo Area, Lower Benue Trough of Nigeria was carried on a map scale of 1:100,000. The area is bounded by latitudes 6^{o}25'N and 6^{o}30'N and longitudes 8^{o} 00'E and 8^{o}05'E respectively and is underlain by shales, limestone, mudstone and lenses of sandstone. These shales have been deeply fractured with major trend in the NE-SW direction. This fracture pattern controls the groundwater movement and hydrothermal enrichment of minerals. They are not only of great hydrogeologic and hydrologic significance since they form semi-confined aquifers which are the major aquifer units in the area, but controls groundwater flow which is vital to man's existence, without it; there would be no life on earth.

Hydrochemical analysis of groundwater of the study area shows that the physical parameters, major cations, major anions, major trace elements and heavy metals in the area are permissible within the WHO (2011) Standard, though, relatively higher than the standard in some locations probably due to the dissolution/hydrolysis of carbonate rocks in those areas. The order of cation chemistry for most of the analyzed groundwater samples is $Ca^{2+} > Mg^{2+} > Na^{+}$ and $> K^{+}$ respectively. The dominant order of anion concentration is $Cl^{-} > HCO_3^{-} > SO_4^{2-}$ >and NO_3^{-}. This suggests that the groundwater is fresh; as total dissolved solid (TDS) is less than 1000mg/l. The groundwater of the study area is of high quality based on the result of the samples of groundwater analyzed. It is not corrosive, turbid and does not call for standard treatment. This is possible due to the geology of the area, structures and the activities of people of the area. Groundwater of the area does not have negative effect on the social-economic development of the area provided the developmental projects are carried out in accordance with the Environmental Standards.

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