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HYDROGEOCHEMICAL EVALUATION OF GROUNDWATER QUALITY OF ABAKALIKI AND ITS ENVIRONS, SOUTH EASTERN NIGERIA

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ABSTRACT: Hydrogeochemical evaluation of groundwater quality of Abakaliki and its environs was carried out on a scale of 1:25,000. The concentrations of selected metals in 25 groundwater samples namely Fe, Pb Zn, Cu, Mn, Co, Ni, Ba, Ag and Cd were determined using Atomic Absorption/emission Spectrophotometer (AAS) 205model. The pH of the sample were determined using a handheld digital pH meter 350 model. The pH values ranged from 6.1-7.0 indicating that the samples are slightly neutral. Analysis for physico-chemical parameters and variables (ANOVA) was done using standard methods. StatistiXL 1.5 was used for performing the grouping. Chemical analysis and various concentrations of the heavy metal loads show that the groundwater has little or no trace of Fe (0.01mg/l) Cu (0.03mg/l) Zn (0.02mg/l) Pb (0.01mg/l) and Co (0.02mg/l) contamination. The concentrations of Fe (0.03 mg/l) Pb (0.01 mg/l),Co(0.03mg/l) and Zn (0.02mg/l) were in compliance with WHO (2011) permissible standard for drinking water while the concentration of Cd ranged from 0.11mg/l to 0.14mg/l and silver 0.06 mg/l to 0.08 mg/l are far above World Health Organisation standards indicating that the area are moderately contaminated with Cd and Ag. The hydrogeochemical analysis carried out during this study stands as a guide to the best sustainable management of some contaminated aquifer systems of Abakaliki and environs. Statistical analysis of variance (ANOVA) revealed that Fe, Cu and Co were significant at $P<0.05$. The analysis reveals that the concentration of the various heavy metal load in the study area decreases away from the source point as in areas near to the Ricemill husk/cluster.

KEYWORDS: Physical Parameters, Chemical Parameters, Asu-River Group, Groundwater and Geochemistry.

1 INTRODUCTION

Groundwater is water that is found in the zone of saturation and occurring naturally in voids. This water is held in the subsurface under the hydrostatic pressure below the water table. They are being exploitated domestically by mechanically drilled wells or boreholes. The quantity, chemical and biological characteristics of the water determine its usefulness for industry, agriculture or domestic purposes. The chemical composition of groundwater and the water types found in an environment are determined greatly by the composition of water of precipitation, local geology, types of minerals found in the environment through which recharge and groundwater flows, anthropogenic activities such as mining and waste disposal as well as climate and topography (Akpa and Ezeigbo *et al.,* 2010). Suitability of groundwater for domestic use is determined by its geochemistry, (Moses et al, 2014.)

There are other factors that affect groundwater chemistry which includes the chemistry of the infiltrating water at the recharge source, the chemistry of the porous media including the interstitial cement or matrix of the aquifer, the rate of groundwater flow in the aquiferous medium and the permeability of the aquifer (Offodile, 2002). Within aquifers, groundwater is hosted by minerals which influence its hydro-geochemistry and ultimate quality (Etu-Efeotor, 1998). The quality of water is determined by its chemical composition and therefore its ultimate usability and its assessment and the parameters examined depend on the envisaged usage. In some cases, water quality is far more important than its availability. On account of the wide variety of water, hydro-geochemical characteristics and the consequent different standards of portability, it is impossible to set rigid standards of chemical quality. The evolution of groundwater is explained by the order of encounter as stated by Freeze and Cherry (1979). This theory states that the order in which groundwater encounters strata of different mineralogical composition can exert an important control on the final water chemistry. As groundwater flows through the strata of different mineralogical composition, the water composition undergoes adjustments caused by imposition of new mineralogically controlled thermodynamic constraints (Edet, 1993).

1.1 Brief Description Of The Study Area

The study area covers Abakaliki and its environs. It extends laterally into Ekaru Inyimagu, Agbaja and Nkwegu all in Ebonyi State (Fig.1) Geographically, the area is located between latitude $6^0 15^I$N and $6^0 20^I$N and longitude $8^0 05^I$E and $8^0 10^I$E covering a total area of about 1,328Sq/km. The area stretches down towards Ogoja Road area off Amachi-Obugha down to Okwerike. Major villages within the study area include Abakaliki, Azuiyiokwu, Sharon and Ugboloke. It has major and minor network of roads connecting each other in the mapped grid.

1.2 Drainage

Surface drainage in the study area is irregular and consists originally of a number of small ephemeral streams. The streams generally flow in N-S direction into Ebonyi River. Ebonyi River is the major river that cut across the study area, the flow of the river during the dry season is nearly zero, implying a negligible baseflow contribution.

Other rivers and smaller streams which contribute to the drainage are Ochaha river, Izicha river and Okwerike river. These rivers and streams vary in sizes, colour, taste, flow path and chemistry. Some are seasonal thereby drying up during the dry season and increase in volume during the rainy season.

The origin of the contaminants from the study area is sourced from heavy metal load intrusions embedded within the aquifer system and human induced pollution activities. Therefore the presence of objectionable tastes, odour, colour as well as harmful substances in such water no matter how abundant it is, render it unsuitable for domestic uses.

2 Geology Of The Study Area

The study area is underlain by the shales of Asu River Group. The Asu River Group is the oldest sedimentary rock in southeastern Nigeria (Reyment, 1965). The shales are exposed variously in the Abakaliki area where they are often referred to as the Abakaliki Shale. The area is predominantly underlain by shale, sandstones, siltstones, sandy shale and limestone. Based on the lithologic, structural and stratigraphic positions, two broad lithostratigraphic units have been recognized. These are Unit A, the light-grey shale and Unit B, the sandstone/siltstone unit. As shown in Fig.1

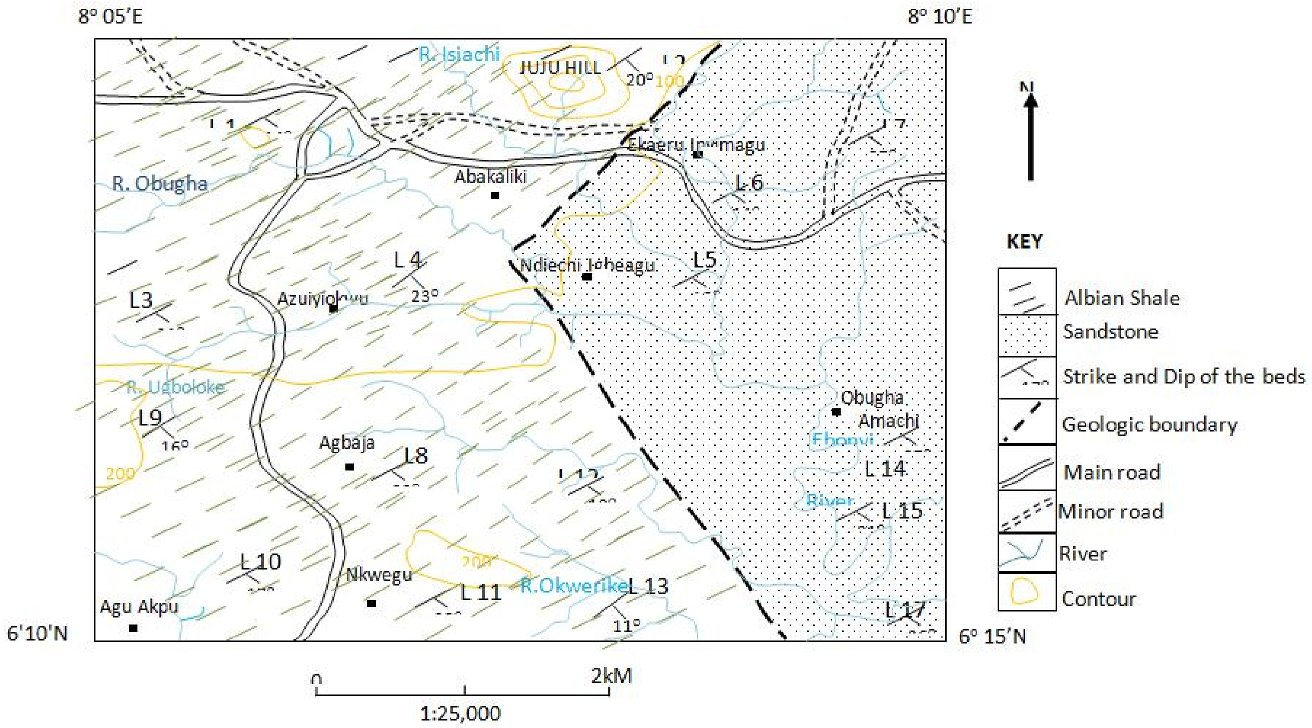

FIGURE.1 GEOLOGICAL AND ACCESSIBILITY MAP OF THE STUDY AREA

3 METHOD OF ANALYSIS

Samples for physical analysis were collected and pH measured by use of PH meter 350model and other parameters measured with turbidity meter (Nephlometeric/606c) Hatch model, odorized kit, colorimetric comparator kit and measuring thermometer. Samples for chemical analysis were collected by the use of polysetheryne free test containers, beakers, round bottom flask, conical flask, fitted lids bottle and measuring cells. The collected samples at the point of collection were stabilized with sodium thiosulphate.

Water samples were collected from groundwater and shallow hand-dug well for hydrogeochemical analysis. A total of twenty five samples were collected randomly from thirty one locations and analyzed (Fig.2). Twenty three samples were collected from boreholes and hand-dug wells while eight were collected from manual drilled hole sources. These groundwater samples were collected by the use of test kits such as Beaker, round bottom flask (calibrated), polysetheryne free test containers and measuring cells. The required volumes usually within the recommending standard of 10ml to 125 ml were pumped into the various measuring containers and stabilized for laboratory analysis. For on-site test for temperature, 125 ml of volume were collected into the wide-mouth glass bottles and then the thermometer was dipped into the sample and allowed for at least three minutes before taking the readings. At each location, observations on the physical aspects of water quality such as colour, taste and odour was done, colour concentrations (test) were analysed in the field by the use of measuring cells known as colorimetric comparator while that of odour was by the use of odorized kit. Samples were collected at each location mainly for heavy metals load concentrations analysis. Samples for heavy metals test were filtered and stabilized with two (2) to three (3) drops of dilute sodium thiosulfate at the point of collection.

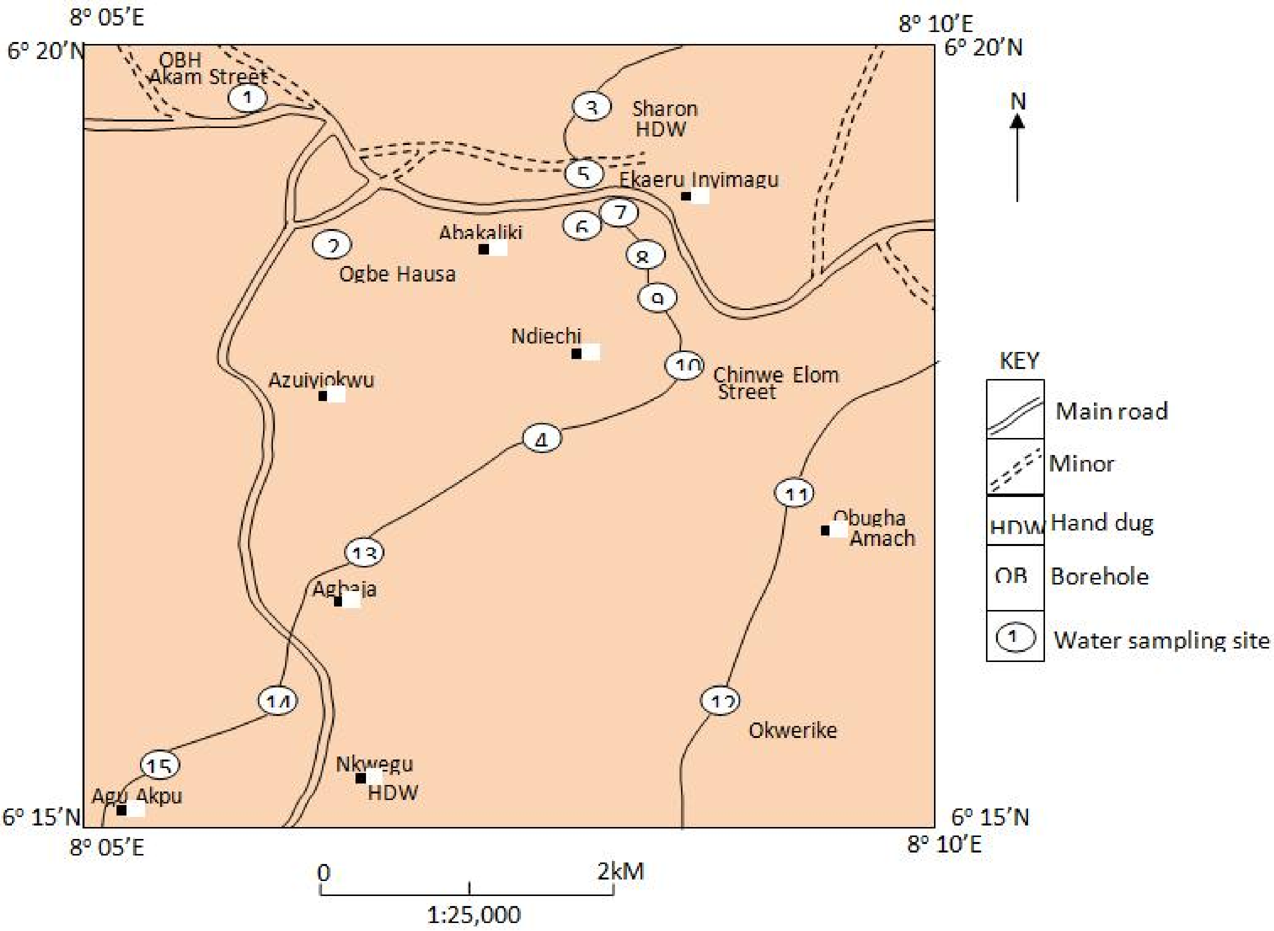

FIGURE 2: MAP SHOWING SAMPLES COLLECTION SITES AND LOCATIONS

4 RESULTS AND DISCUSSIONS

4.1 PHYSICAL PARAMETERS

Physical parameters include pH (H^+ concentration), turbidity; electrical conductivity and colour. The pH of groundwater in the study area ranges from 6.1 to 6.7, while that of shallow hand-dug well ranges from 6.8 to 7.0. This indicates that the water is slightly neutral in most places. The pH fall within the permissible standard for the WHO guideline for drinking water which is between 6.5-8.5. as shown in Fig.3. The turbidity of the groundwater sample in the area ranges between 5-8 mg/l, and that of hand-dug well ranges between 5-6 mg/l. By the WHO standard (2011) turbidity, exceeding 5mg/l is not good for domestic use. Therefore, majority of the available water sources in the area are considered turbid. The conductivity of groundwater samples ranges between 0.12-.10 S/m. This conductivity does not exceed the WHO standard. It is worthy of note that conductivity in the area decreases away from the shallow depth water.

TABLE 1: RESULTS OF PHYSICAL PARAMETERS IN SOME OF THE WATER SAMPLES ANALYZED

Sample location	Sample No	Temperature (°C)	pH	Turbidity (mg/l)	Electrical Conductivity (S/m)
Ogbe Hausa	CAP/02	27	6.1	5	0.18
Okwerike	CAP/04	26	6.8	7	0.11
Sharon (HDW)	CAP/05	26	6.8	6	0.19
Amachi P/g	CAP/06	26	6.8	6	0.19
Azuiyiokwu	CAP/11	26	7.0	5	0.12
Cas Cpd	CAP/14	26	6.7	9	0.13

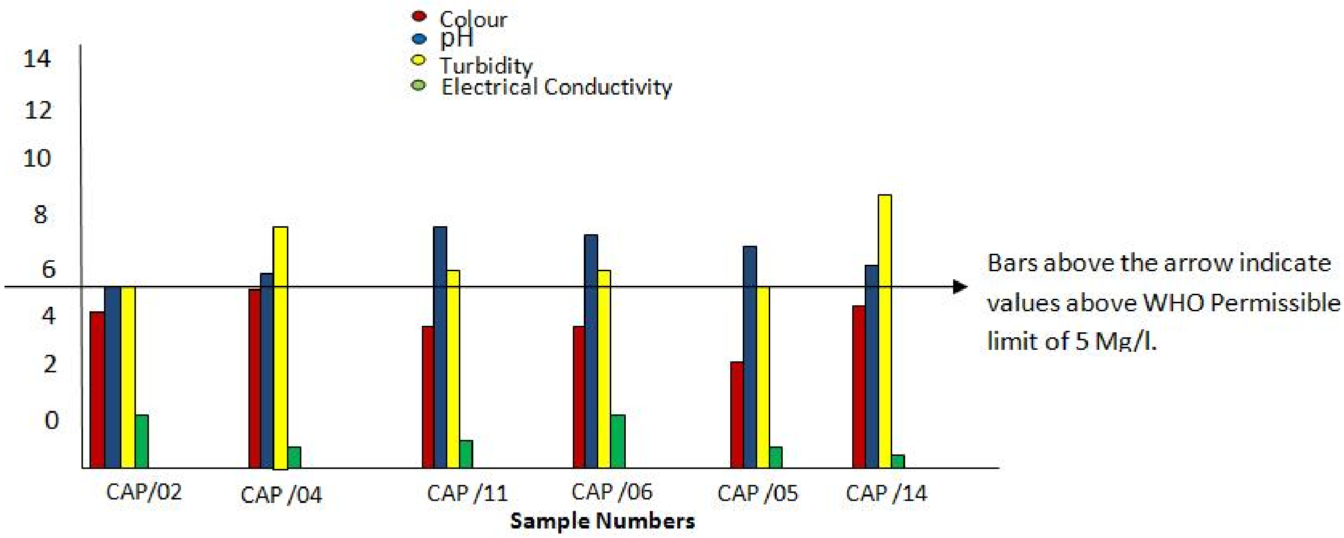

FIGURE 3: DISTRIBUTION OF PHYSICALS PARAMETERS IN GROUND WATER OF ABAKALIKI AND ENVIRONS

4.2 Chemical Parameters

Studies of the various water samples showed that silver has its maximum concentration value of 0.08mg/l at location 11, (Azuiyiokwu) and minimum concentration of 0.02mg/l at location 12, (Nkwagu).

Places such as locations 04 (Okwerike), location 06; (Amachi) and location 01 (Akam Street) show significant decrease in concentration levels from 0.0mg/l to 0.03mg/l. The results indicated that the sampled water are safe for domestic use and are in compliance with WHO (2011) standard for drinking water. The concentration of nickel in the borehole analysed are low on account of the values recorded in Okwerike, Agbaja and Azuiyiokwu. These areas have concentrations of 0.10 mg/l, 0.01 mg/l and 0.01 mg/l respectively and were within the WHO standard for drinking water. The concentration of copper in the study area ranges from 0.01mg/l (24 Waterworks road) to 0.04 mg/l (Nkwagu). These results indicate that most of the areas studied has concentration levels that are in accordance with WHO (2011) permissible standard for drinking water. Reports from the study reveals that barium has minimum concentration levels from 0.10mg/l to 0.80 mg/l. This implies that places like Okwerike, Agbaja, Amachi and Chinwe Elom Street has concentrations that are safe for domestic use. Manganese levels recorded in the borehole analysed are moderately low (0.10mg/l - 0.15mg/l). It has its maximum concentration level of 0.15mg/l at Building Materials, this slight increase is as a result of the exposure of the groundwater sources to metallurgical influences from electric welders, cement stores and pipes (galvanized) packed indiscriminately at the market surroundings. Wells exploited in this vicinity are susceptible to contamination due to the presence of these induced human factors. Cadmium concentration from the study area maintain variability level from 0.11mg/l to 0.14mg/l. These concentrations are reflections from the results of locations 02 (Ogbe Hausa Quarters), 06 (Amachi Community Primary School). This indicates that such places are moderately contaminated and not fit for human and domestic uses. The concentrations of lead from the study area ranged from 0.02mg/l to 0.08mg/l. This implies that water sources in the area has higher concentration that are far above WHO (2011) standard which indicate a permissible value of 1.0mg/l.

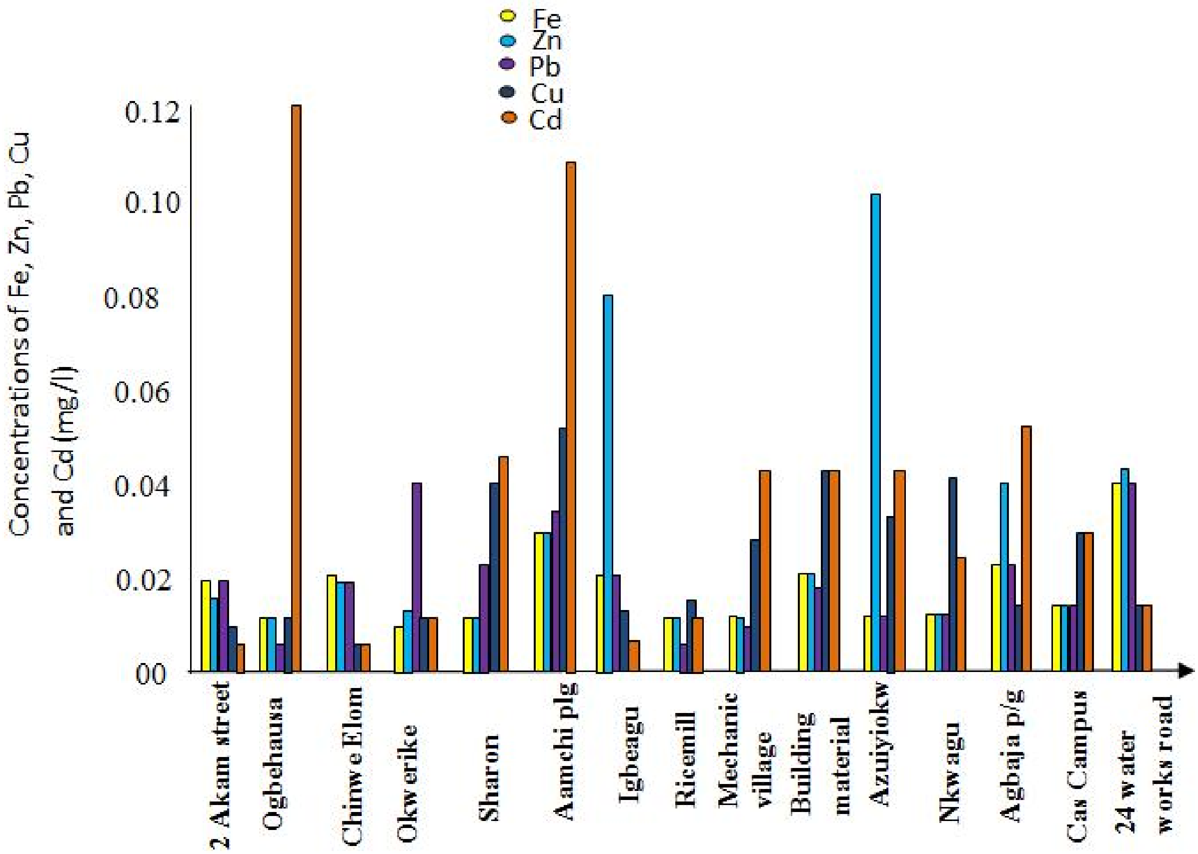

FIGURE. 4: DISTRIBUTION OF IRON, ZINC, LEAD, COPPER AND CADMIUM IN GROUND WATER OF ABAKALIKI AND ENVIRONS

TABLE 1: CONCENTRATION OF CHEMICAL CONSTITUENT IN BOREHOLE WATER SAMPLE ANALYSED

Borehole location	Borehole Depth (feet)	Sample No	Appearance	Colour	Odour	Q/ taste	Temp. °C	EC	Turbidity	Mn	Co	Ni	Ba	Ag	pH
2 Akam street	6.0	CAP/01	C	C	un obj	Obj	27°	0.18	7	0.02	0.03	0.03	0.06	0.01	7.0
Ogbe Hausa	8.20	CAP/02	C	C	un obj	Un obj	27°	0.18	5	0.03	0.08	0.05	0.07	0.03	6.1
Chinwe Elom street (Hiitop)	6.40	CAP /03	C	C	un obj	Obj	27°	0.19	6	0.07	0.06	0.02	0.10	0.01	6.8
Amachi pls	6.20	CAP /06	C	C	un obj	Obj	25°	0.12	8	0.08	0.05	0.10	0.09	0.03	6.4
Igbeagu	9.00	CAP /07	C	C	un obj	Obj	25°	0.16	7	0.03	0.06	0.04	0.02	0.02	6.7
Rice mill	8.70	CAP /08	C	C	un obj	Obj	27°	0.15	6	0.01	0.04	0.05	0.23	0.05	6.8
Mechanic village	4.20	CAP /09	C	C	un obj	Obj	26°	0.10	6	0.08	0.04	0.05	0.05	0.01	6.9
Building Material	7.10	CAP /10	C	C	un obj	Obj	26°	0.15	7	0.15	0.02	0.02	0.03	0.04	6.8
CAS CPD	6.8	CAP /14	C	C	un obj	Obj	26°	0.13	7	0.06	0.02	0.03	0.08	0.04	6.7
24 Water works	5.00	CAP /15	C	C	un obj	Obj	25°	0.17	8	0.01	0.02	0.01	0.01	0.01	6.8

KEY: Obj = Objectionable, Unobj = Unobjectionable, Nc = Not Clear, C = Clear

TABLE 2: CONCENTRATION OF CHEMICAL CONSTITUENT IN BOREHOLE WATER SAMPLE ANALYSED

Borehole location	Borehole Depth (feet)	Sample No	Appearance	Colour	Odour	Q/ taste	Temp°C	EC	Turbidity	Fe	Zn	Pb	Cu	Cd	pH
2 Akam street	6.0	CAP/01	C	C	un obj	obj	27°	0.18	7	0.02	0.01	~~0.03~~	0.04	0.02	7.0
Ogbe Hausa	8.20	CAP/02	C	C	un obj	Un obj	27°	0.18	5	0.01	0.04	0.01	0.01	~~0.11~~	6.1
Chinwe Elom street (Hiitop)	6.40	CAP /03	C	C	un obj	obj	27°	0.19	6	0.02	0.02	~~0.02~~	0.05	~~0.04~~	6.8
Amachi pls	6.20	CAP /06	C	C	un obj	obj	25°	0.12	8	0.03	0.01	~~0.08~~	0.05	~~0.14~~	6.4
Igbeagu	9.00	CAP /07	C	C	un obj	obj	25°	0.16	7	0.02	0.05	~~0.07~~	0.01	0.01	6.7
Rice mill	8.70	CAP /08	C	C	un obj	obj	27°	0.15	6	0.01	0.03	~~0.03~~	0.01	0.02	6.8
Mechanic village	4.20	CAP /09	C	C	un obj	obj	26°	0.10	6	0.01	0.05	0.01	0.04	~~0.04~~	6.9
Building Material	7.10	CAP /10	C	C	un obj	obj	26°	0.15	7	0.02	0.01	~~0.02~~	0.04	~~0.04~~	6.8
CAS CPD	6.8	CAP /14	C	C	un obj	Obj	26°	0.13	8	0.01	0.01	0.01	0.03	~~0.04~~	6.7
24 Water works	5.00	CAP /15	C	C	un obj	obj	25°	0.17	8	0.04	0.02	~~0.04~~	0.01	0.02	6.8

Striked values are values above World Health Organization (2011) permissible standards.
KEY: Obj = Objectionable, Unobj = Unobjectionable, Nc = Not Clear, C = Clear

5 SUMMARY AND CONCLUSIONS

Water contamination is generally considered to occur where contaminants attain concentration levels that are considered to be objectionable. Based on the results analyzed, numerous sources of water contamination exist in the study area, some of the point sources are the dumped chemical wastes from Ebonyi State Fertilizer Plant (Azuebonyi) and Rice milling factory where rice husk/cluster are evacuated. Results showed that cadmium and lead contents of the boreholes closer to the rice husk exceeds the objectionable limit at the sample site. Water samples collected at locations, 09, (Mechanic Village), 03 (Chinwe Elom street) and 014 (Cas Compound) and those collected at location 06 (Amachi) and 02 (Ogbe Hausa) has concentration levels that are above World Health Organization (WHO, 2011) permissible standard guideline. These points must be treated before there are safe for domestic uses. Physical parameters obtained from the analysis such as pH and turbidity reveal that the water is slightly neutral to fairly acidic in most places. Turbidity at some areas are far above the WHO (2011) recommended Standard for drinking water. At Ogbe Hausa and Mechanic village site, human pollution is the potential source of these contamination because human used solid and semisolid wastes from the environment are disposed indiscriminately near the water course, hence the groundwater near such area are contaminated. Results equally indicate that mineral ores such as carbonate ores embedded in the rock units hosting the groundwater are medium of contamination since some has metal loads that are above WHO requirements. Geologic investigations showed that Abakaliki shales and sandstone aquifers hosts majority of the heavy metal load concentration which made some groundwater here unsafe and requires treatments before domestic use.

6 RECOMMENDATION

Water quantity is as important as its quality. Based on observations from this study, proper sewage disposal system should be provided and upheld in the study area and this will minimize the rate and distribution of chemical constituents, which emanate from sewage disposal. Further geochemical investigation should be conducted before boreholes are sited in these areas. This will reduce the incidence of any outbreak of water borne diseases. Finally, small-scale reservoir (concrete tanks) could be built near the boreholes. The groundwater would be firstly pumped into such systems and allowed to aerate to reduce the high concentration of dissolve constituents before domestic use. The use of PVC pipes where appropriate would alleviate the problem of corrosion of galvanized pipes.

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