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Appraisal of the Groundwater Quality in Arochukwu Area, Afikpo Basin, Nigeria

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ABSTRACT

Detailed study of the physical and chemical quality analyses of several groundwater samples was carried out in an attempt to assess the potability of groundwater in Arochukwu area. A total of 10 numbers of boreholes were involved in the water sampling for quality analysis. The waters did not have objectionable colour, odour or taste and were not turbid. The pH have mean values of 6.72, this shows acidic and aggressive groundwater in the area. The dominant cations include Ca^{2+} with mean values of 18.6. The Carbonate, Nitrate and Sulphate dominate the anion. CO_3^-, NO_3^-, SO_4^{2-}, and have mean values of 17.90, 0.049, 6.12, mg/l respectively. The groundwater in the area is generally soft, and free from saltwater intrusion, with low iron constituents .Therefore, the groundwater of the area is generally of acceptable quality for household, industrial and agricultural purpose.

Keywords: *Carbonate, Groundwater, Aftkpo, Quality*

I. INTRODUCTION

Groundwater provide, more than half the drinking water consumed by Arochukwu Community today. The advantages of groundwater over other sources are enormous. Generally, it is free of pathogenic organisms and needs no purification for domestic or industrial uses, the temperature is nearly constant, turbidity and colour are generally absent, chemical composition is commonly constant .The quality of water usually available for exploitation is often limited by the geography and geology of the area under consideration [1]. There are discharge areas, where groundwater rises to the surface, and recharge areas, where rain and run-off percolate down to replenish supplies.

The groundwater movement is affected by the type of rock comprising the aquifer; water moves quickly through loosely packed layers of rock, slowly through more impermeable ones [2]. Shallow unconfined aquifers are more vulnerable to contamination than are deep ones protected by overlying layers of rock [3]. Everyday activities of people in an area can bring about possible pollution of groundwater, activities like changing of used engine oil which are left to be washed away by the next rain, others are herbicide, fertilizer, deliberate dumping of waste, leaks from underground tanks (mainly gasoline), septic tanks [4,5].

It is therefore imperative to determine the suitability of groundwater before use. The chemistry of groundwater in any geological environment is controlled by several factors viz: the chemistry of the infiltrating water at the recharge source, the chemistry of the porous medium including the interstitial cement or matrix of the aquifer, the rate of groundwater flow, in the aquiferous medium and hence the permeability of the aquifer and the travel time of the water through the environment. The quality of water for various purpose, viz: domestic, irrigation and industry, depends on the concentration of these substances [6]. Results of water quality are usually compared with establishment by international regulatory bodies such as the World Healt Organizations (WHO), Federal Environmental Protection Agency (FEPA) and National Agency For Food, Drugs and Administrative Control (NAFDAC). This research work is prompted by the ever increasing population in the study area, that depend heavily on groundwater and the fear that continual abstraction could lead to environmental problems such as saltwater intrusion, subsidence or water crisis.

Location of Study Area

The study area is located in the Arochukwu Area, Afikpo Basin. It is situated between latitude 6.°11’ and longitude 7°.10’.

II. RESEARCH OBJECTIVES

To study the physical and chemical water qualities of the groundwater within the area, to determine the dominant cations and anions and their influence on the groundwater of the area, compare the results of the study with international specification (WHO Standard) in order to determine their suitability for domestic use.

Geology and Hydrogeology of the Afikpo Basin

The Study area, Arochukwu lies within Afikpo Basin in the Lower Benue Trough and has the following lithostratigraphic divisions [8, 9].

Asu River Group: This is a sequence of marine shales occupying the core of the Abakaliki Anticlinorium. It has a thickness of about 6000ft, embedded with shale and micaccous sandstone and the shales are deeply weathered and contains radiolarian echinoids, pelecypods and gastropods . The Age is Albian.

Eze-Aku Shale Group: The Eze Aku Shale group consist of hard grey to black shale having thick flaggy calcareous and non-calcareous shale. The Eze-Aku Formation represents a shallow water deposit The fossils consist of mainly pelecypods, gastropods, echinoids, e.t.c which indicate basal Turonian age.

Agwu Shale: The Agwu Shale overlies the Eze Aku shale comfornably and is between Agwu and Ndeaboh in Southern eastern Nigeria. The lithology is bluish-grey well-bedded shale interbedded with fine yellow calcareous sandstone and shaly limestone with a total thickness of 900m, the strata are greatly folded and contain oil seeps.

Nkporo Enugu shale and Owelli sandstone: Nkporo shale of Late Campanian age is the basal facies of the late Cretaceous sedimentary cycle in the Anambra basin. Exposures are poor, bearing coarsening upward deltaic sequences of shales interbedded with sands. This interpretation is supported by the vertical association of distributary channel sands (basal Mamu formation) and the lateral equivalents of lower flood plain carbonaceous shales (Enugu shales) towards the central and northern parts of the basin. The lithology of Enugu shales consists mainly of carbonaceous shales and coals within the upper half deposited in lower flood plain and swampy environments. The sediments are normally associated with siderites and pyrites which are early diagenetic minerals.

The Owelli sandstone is the major sand member of the Enugu shale formation and forms and elongate shoestring sand body elongated to the NE defining a meander belt of a fluvial/distributary channel system. Sedimentary structures of the channel sand exposed at the junction, for instance demonstrates possible tidal processes coupled with a few gastropod shells recovered, suggesting marine incursions into these distributary channel systems.

Mamu Formation: The Mamu Formation overlies the upper Campanian lateral facies associations described above. The age ranges from lower to middle Maastrichtian from south to north. Both vertical and lateral facies changes are observed, formation thickness ranges from l00m to l000m across the basin and lithology includes shales and sandstones, with some limestones in the south and coal seams in the central to upper parts of the basin. Depositional environments include distributary/estuarine channels, barrier foot, swamp and tidal flats.

The Ajali Sandstones: The Ajali sandstone consists of mineralogically much matured, medium to coarse grained, moderately well sorted quartz grains, and intercalations of thin laterally extensive clay, beds of normally less than 1m also occur. The formation thickness is about 300m extending across the entire basin and into the middle Niger Basin and slightly diachronous, ranging from Middle to Late Maastrichtian from south to north.

Nsukka Formation: The Nsukka Formation (Upper Coal Measure) lies conformably on the Ajali Sandstone. It occurs from the north of Awka to the Upper Ankpa sub-basin, with lithology of mainly shales, siltstones, sands and coals and lateritic cover. Age of the formation is from upper Maastrichtian to Danian, and depositional environment is similar in many respects to the Mamu Formation (lower coal measures), consisting of transitional/shoreline, mudflats and swamps, deposited during a largely regressive phase of sea level changes.

Climate and Drainage

The climate of the study area is that of tropical rainforest with distinct wet and dry seasons. The wet season is characterized by a period a prolonged period of rainfall which extends from April to October, while the dry season is characterized by a period of dry hot weather. This season extends from November to March including the harmathan period (Offodile, 1992). The mean annual rainfall ranges from 19,900mm to 2,200mm (Offodile 1992). The main water-bearing geological formation in the area is the late Maastrichtian Ajali Formation. The Formation consist of a quartz arenite, loose angular to sub-rounded grains. The grain size of the area has a multi-modal distribution. The Ajali Formation has a thickness of about l00m in the area and it is exposes along road cuts and stream valleys. Some proportion of the rainfall is lost by run-off and evapotranspiration. The area is dissected by a dense network of rivers, which maintain a delicate but dynamic equilibrium between estuarine and freshwater surface bodies with complex underground extensions . A close observation of the rivers in the study area and its environment shows that the network pattern created does not easily fit the convectional, typical dendritic and trellised pattern of drainage. The entire area is criss-crossed by several rivers.

III. METHODOLOGY

Water Sample Collection: Groundwater samples were collected in the sterilized two litre containers tightly fitting covers wrapped in black polyethylene plastic bags and put in a cooler to ensure constant temperature. The samples were collected in 12 containers, 10 for the analysis of the cations/anions while other 2 were used for microbial analysis. The samples were immediately transported to the laboratory for analysis.

Laboratory Analyses for Water Quality Parameters

All analyses were carried out at a standardized laboratory, using standard methods. The evaluation of water quality was in accordance with the regulatory standards set by the Federal Environmental protection Agency FEPA (1991). The approach ensures that the samples collected were tested in accordance with agreed requirements.

Temperature, Conductivity and Total Dissolved Solids (TDS)

Temperature, conductivity and TDS of the water samples were determined electiometrically with a multiparameter datalogger (Hanna Model No.11 1991300). The meter was calibrated prior to use with 0.001 N and 0.10 N standard potassium chloride solutions (according to the manufacturers specifications) and buffer standards, (obtained from accustandards) of pH 4.7 and 10 at room temperature. The analysis involved dipping the probe of the meter directly into the sample in the 2 litre plastic can, then taking the reading as displayed on the screen of the equipment. After each measurement, the probe was rinsed in distilled water and the display mode adjusted to the standardization value for measurement of the next parameter.

Total Alkalinity and Hardness

Total alkalinity is a measure of bicarbonate, carbonate and hydroxide ions. In most natural waters, the principal anions is bicarbonate with carbonate and/or hydroxyl ion being present only if the $_pH$ is greater than 8.3 (UNICEF UNESCO, 1979). Total alkalinity was determined in accordance with American Standard for testing and Materials (ASTM) D1067B method, in which 0.lm hydrochloric acid stock solution was prepared then diluted to a working solution of 0.0l ml. The l00ml of the sample was measured in a conical flask and three drops of phenolphthalein indicator was added drop wisely as the flask was swirled until stable colour changed to pink was observed, The sample solution was then titrated against 0.0lm hydrochloric acid to a colourless endpoint after which 3 drops of methyl orange indicator were added and the titration continued to an orange colour end.

The total volume of acid used was recorded. Blank analysis was carried out using 0.0lm hydrochloride and the total volume added was also recorded. Water hardness is the traditional measure of the capacity of water to react with soap. Hardness of water is the property attributable to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) as the principal alkaline earths in natural waters. Fe^{2+} can also cause water hardness. Hardness was determined by the reaction of the bivalent metallic ion present in water sample with a chelating agent such as Ethylenediaminetetracetic (EDTA). It is expressed as an equivalent of calcium carbonate.

Turbidity: Turbidity of groundwater is largely a value reflecting the particle size of suspended matter in the water sample; it is not a measure of the amount material in it. Turbidity was determined in accordance with APHA 21300B. A calibrated turbidity spectrophometer- ELE Paqualab model 1930712 was used. The turbidity meter has a range of 0-174 NTU, Distilled water was used to calibrate the equipment to zero level, and a standard set according to manufacturers specification. The sample was transferred into a Cuyette and placed in the sample holder, the turbidity values was obtained by turning a dial knob to display the reading in NTU

Oil and Grease: Oil and grease were determined in accordance with America Standard for Testing and Materials (ASTM) D3921. This involved the use of transform infrared spectrophotometer (FTIR) Genesis series instrument prior to analysis; the sample was extracted into a 250 ml separator funnel with 20 ml of carbon tetrachloride. The equipment was calibrated with a blend of light and medium crude oil dissolved in the carbon tetrachloride. Ranges of the blend between 50 and 600mg/l were prepared as calibration standard and extrapolated on graph, in the FTIR. Oil and grease concentration in the sample was determined by using the stored calibration graph in the software of the equipment as reference.

Nitrate and Sulphate: Nitrate was determined colometrically using Unicarm UV/visiblespectrophometer. 1 ml of the sample was analyzed directly using brucinesulphate as a complexing agent in the presence of sulphuric acid and measured at a wavelength of 470nm. Phosphate was determined in accordance with APHA 414E, also a metric method, but based on a blue complex induced by the addition stanmous chloride. The sample was analyzed at a wavelength of 690nm with Unicam UV/visible spectrophmeter. Sulphate was determined in accordance with APHA 426C - arbidimetric method based on barium chloride as the precipitating agent 'mistformer'. 100ml of the sample was analyzed at a wavelength of l20nm in a UV/visible spectrophometer.

IV. PRESENTATION OF RESULT

Physical and Chemical Parameters of Water Quality Analysis: The result of the laboratory water quality analysis of major anions/cations and physical parameters of the groundwater in the study as determined from the procedures outlined are as presented in Table 1 inclusive (see last row) is World Health Organization (WHO, 1992) minimum specification of the various water quality meters for the purpose of comparison with field values. Values are compared with WHO (1992) minimum specification.

V. DISCUSSION OF RESULT

Physical Parameters

The average $_{p}H$ values of the study samples is 6.12 These values fall below WHO (1992) stipulation of 6.5-8.5, the results show that groundwater in the area is slightly acidic. The acidity is probably caused by the presence of organic matter in the soils. Moreover, free CO_2 from the atmosphere can also enter the groundwater system as rainwater percolates underground and reduce the H of the water. Acidic waters are favourable to the growth of iron bacteria which cause incrustation of pipes [10].

Turbidity results ranges from 0.10 to 1.40 units which is low as compared to 50 units stipulated by WHO (1992). Turbidity is caused by several types of suspended inorganic material such as suspensions of clay, small particles of ferric oxide which may come from rusty casings. Turbidity of groundwater is usually known to be minimal compared to surface water; cases of turbid water occurrence have been known to result from poor well construction and development.

The conductivity varies from 7.10-11.90 us/cm showing that the water is good, fallen below WHO (1992), stipulated range. It is also excellent for agricultural purpose because it's conductivity does not exceed 250us/cm. Above all the presence of unobjectionable tastes, odours or colours, makes it good for most purposes

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Chemical Parameters

The chemical and biological characteristics of water determine its usefulness for industry, agriculture or domestic purposes. The purpose of this section is to discuss the general occurrence of the various constituents in water and to mention briefly the relation of these constituents to water use.

Calcium (Hardness): Hardness in water results from the presence of divalent metallic cations, of which calcium and magnesium are the most abundant in groundwater. These ions react with soap to form precipitates and with certain anions present in the water to form scales. Because of their adverse action with soap, hardwaters are unsatisfactory for household cleansing purpose .
However, calcium (hardness) varies from 2.55mg/l to 5.30 mg/l, WHO (1992) have stipulated that the value should not exceed 500mg/l. The degree of hardness in water is commonly based on the classification after Tebbutt [10], based on this classification (Table 2), water in the area could be said to be soft for domestic and agricultural purposes.

TABLE 2: Classification of Hardness

Hardness	Water Class
0-75	Soft
75-150	Moderately hard
150-300	Hard
Over 300	Very Hard

Carbonates: The carbonate level ranges from 11.80mg/l to 31.60mg/l. This is far below the expected range of 120mg/l stipulated by WHO (1992). It is noteworthy that carbonates and bicarbonates ions produce alkalinity. Alkalinity is therefore a reliable-measure of carbonate and bicarbonate for most natural water. Most carbonate and bicarbonate ions in groundwater are derived from carbon dioxide in the atmosphere, carbon dioxide in the soil and solution of carbonate rocks. Temporary hardness is caused by presence of these ions in water for containing large amounts of bicarbonate and alkalinity is undesirable in many industries [10] .

Nitrates: They are derived from the atmosphere, legumes, plant debris, and animal excrement and are known to cause physiological distress and bitterness when it exceeds more than 100 mg/l (WHO, 1992).However, the values in the study area fall in the range of 0.02mg/l to 0.08mg/l. It has been reported that water from shallow wells containing more than 45mg/l can cause methemoglobinenia in infants.

Sulphate: They are usually derived from oxidation of sulphide ores; gypsum and anhydrite. Sulphates combine with calcium to form an adherent, heat retarding scale. More than 250mg/l is objectionable in water in some industries. Water containing about 500mg/l of sulphate tastes bitter and water containing about 1000mg/l may be cathartic. The value obtained within the study area fall within the range of 4.40mg/l to 7.30mg/l, the values is far below the maximum range of 200mg/l stipulated by
(WHO, 1992).

According to Hem pH of water represents interelated result of a number of chemical equilibria [6]. The equilibria in a groundwater are altered when the water is taken into a well and pumped to surface. He opined further that natural waters whose pH is below 4.5 contain low proportion of dissociated or undissociated and carbonate ion. Most commonly the source involves a reaction that involves oxidation of some form of sulphur.

The low pH value in the area, according to may have been caused by the presence of organic matter in the soils. Free $Co_2$from the atmosphere can also enter the groundwater as rainwater percolates underground and reduce the pH of the water. The pH of the water controls a lot of ionic reactions in water. The pH of water can also affected by oxidation of ferrous ion [6, 7].

VI. CONCLUSION

The result of the geochemical analysis on groundwater within Arochukwu area reveals that existing water boreholes have pH of average values of 6.12, that is, slightly acidic. The water is therefore expected to be aggressive .

The analytical results in the area show that groundwater in the area is soft and low in dissolved constituents. The water can be treated. The pH can be adjusted to between 7.0 and 8.5 by addition of lime. Evaluation of the results shows that the water is suitable for drinking and other domestic purposes. All the constituents fall below the WHO (1992) standard. Biological analysis shows that, the water in the area does not pose any threat to life. However, in the view of Offodile [7], deep wells are the best for area with acidic groundwater. Sources of contaminants in the area such as indiscriminate disposal of waste can be managed to curb the long-term effect that could emanate from such practices.

However, it is important to note that water of very low pH may result from discharge of industrial wastes and drainage from mines, this can carry high concentrations of ferric and ferrous iron. The measured values of pH, sulphate, nitrate, carbonate, calcium, hardness, conductivity, turbidity when compare with WHO show that they all fall within acceptable limits except the pH value that is expected to be buffered.it is also recommended that PVC pipes and other non-corrosive materials should be used for borehole construction in the area [11].

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Table 1: Quality of Groundwater in the Study Area

Location	PH	Turbidity	Cond.	Ca (Hardness)	Carbonate	Nitrate	Sulphate	Iron
A	6.08	0.20	9.40	3.22	12.50	0.07	6.75	0.20
B	6.45	1.4	8.20	2.85	13.40	0.08	5.80	0.40
C	6.51	0.3	10.40	2.55	15.70	0.03	5.70	0.06
D	6.86	0.05	7.20	5.30	28.50	0.04	6.30	0.18
E	7.20	0.3	8.70	3.70	31.60	0.03	5.20	0.10
F	6.32	0.40	9.30	4.65	22.50	0.02	7.30	0.07
G	7.48	0.16	8.70	3.38	16.10	0.06	4.40	0.08
H	6.53	0.32	11.90	5.30	12.80	0.04	6.20	0.16
I	7.07	0.10	9.30	4.90	11.80	0.05	6.30	0.20
J	6.06	0.60	7.10	4.20	14.10	0.07	7.20	0.06
W H O LIMIT	**6.5-8.5**	**50**	**1400**	**500**	**500**	**100**	**200**	**0.3**