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ASSESSMENT OF SHALLOW GROUNDWATER QUALITY AND ITS SUITABILITY FOR DRINKING AND AGRICULTURAL USES IN PARTS OF AHOADA EAST, RIVERS STATE, NIGERIA

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ABSTRACT

This study aims at determining the quality of the groundwater in parts of Ahoada East, Rivers State, Nigeria to establish its suitability for domestic, agricultural and industrial purposes. Ten (10) groundwater samples were obtained from boreholes and analysed using standard methods. The result shows a low p^H value ranging from 4.66 – 5.92 with a mean value of 5.25. The iron content of nine (9) borehole samples was high except for borehole 1(AH_{1}) which show a significantly low iron content. Other parameters met the World Health Organization (WHO) standards for drinking water and domestic usage. The Sodium Adsorption Ratio is low, making it suitable for irrigation. For industrial purposes, the water should be treated according to the industrial process in view before usage. Furthermore, water for drinking should be treated mildly, due to low p^H and high iron content. Polyvinyl chloride materials (PVC) and other non-corrosive materials should be used for the construction of boreholes within the area to reduce damage to plumbing materials. Groundwater monitoring, effective and holistic management strategy should be employed in the study area.

Key Words: Groundwater, hydrogeochemistry, water quality, Ahoada, Rivers State, Nigeria

INTRODUCTION

Water is an invaluable and vital resource for life sustenance. Globally, irrigated agriculture is the largest abstractor and predominant consumer of groundwater resources, with important ground water-dependent agro economics having widely evolved. Water plays an important role in promoting agricultural production and standard of human health (Sudarsana*et al*., 2013).

Groundwater is a 'very popular commodity' with farmers since it is usually found close to the point-of-use. Groundwater can be developed quickly at low capital cost by individual private investment and is available directly on-demand for crop needs (given a reliable energy source for pumping). It also affords small-holders a high level of control year-round and is well-suited to pressurized irrigation and high productivity precision agriculture. It has 'democratised' irrigation by permitting irrigated agriculture outside canal command areas. In developing and transforming nations the 'groundwater-irrigation boom' occurs at various economic levels (Garduno and Foster, 2010) – from subsistence farming to large-scale staple-crop production and commercial cash-crop cultivation. It has brought major socioeconomic benefits to rural communities and in many countries has helped to alleviate agrarian poverty through increasing food security – by ensuring water availability at critical times for crop growth and mitigating devastating effects of drought on crop yields (Shah, 2009).

Rapid industrialization, urbanization and population growth has put tremendous pressure in the degradation of both surface and groundwater quality (Dash & Sahoo, 2013). Both geogenic and anthropogenic reasons are responsible for groundwater quality degradation. In the study area, private boreholes and hand dug wells are the major source of water supply. The public water supply system is lacking as there is lack of political will on the side of government to provide its teeming population with safe, affordable water which has adversely affected the pace of development and contributed to rapid spread of water-borne diseases.

Nwankwoala and Udom (2008, 2011a), acknowledged that the groundwater quality in the Niger Delta is rapidly deteriorating. Furthermore, groundwater abstraction is done indiscriminately without a good knowledge of distribution geometry, safe yield and water variation in the different horizons that make up the aquifer (Etu-Efeotor and Akpokodje, 1990).Moreover, the hydro-chemical processes and characteristics of the aquifer systems in part of the Eastern Niger Delta are generally not known due to an overall lack of hydrologic and hydro-geologic data which complicates planning and management of groundwater abstraction (Abam, 2001). This study therefore aims at evaluating the hydro-geochemistry of Ahoada, Ahoada East Local Government Area of Rivers State, with emphasis on water quality of the area.

MATERIALS AND METHODS

Study Area

The study area, Ahoada East Local Government Area is located in the Eastern Niger Delta Basin of Nigeria lies between latitude 5°4′0″N, 5°6′0″N and longitude 6°38′0″E, 6°38′0″E (Fig.1). The area is accessible by road through the East West Road from Port Harcourt and Bayelsa State. The study area could also be accessed from Ogba-Egbema-Ndoni Local Government Area. Several scholars have extensively studied the hydrogeologic condition in the Niger Delta. The study area lies within the Benin Formation in the Niger Delta. From the study by (Etu-Efeotor, 1981; Etu-Efeotor and Odigi 1989; Amadi*et al.*, 1989), (Etu-Efeotor and Akpokodje, 1990), Udom*et al.*, (1998, 1999, 2002), Akpokodje (2001), Nwankwoala and Udom(2011a) results shows that there exist multi aquifer system in the Niger Delta.

The depths to water table decreases seaward from 10m inland (Elele) to less than 0.5m at the Coastal areas (Bonny) as suggested by Akpokodje (2001). Generally, groundwater in River State is tapped from the upper section of the Benin Formation and the aquifers are predominantly sand beds, with minor clays, lignite and conglomerate intercalations resulting in a multi aquifer system.

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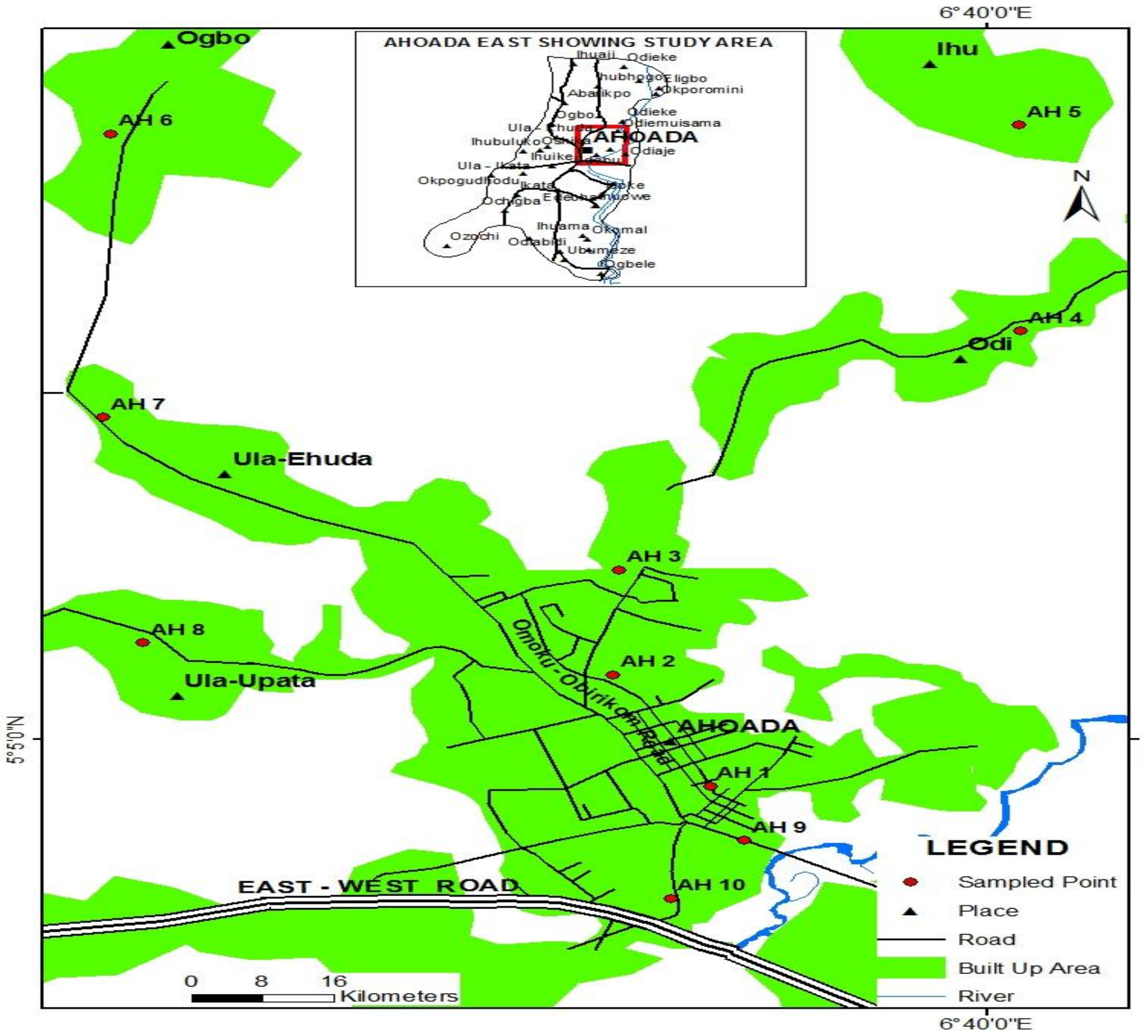

Fig.1: Map of Ahoada East showing Sampling Points

Methods of Investigation

Ten (10) water samples were collected in parts of Ahoada. The water samples were collected in thoroughly cleaned plastic containers of 1.5 liter capacity provided with double cap devices. The samples were preserved with few drops of Nitric acid (HNO_3). After sampling, the lids of the containers were immediately replaced to minimize contamination and escape of gases. The samples were then stored in a cooler and transported to the laboratory for analysis. The laboratory analysis of physical - chemical parameters was done in ZettaAllied Digital Energy Limited, Port Harcourt, Nigeria using standard techniques provided by the United States Salinity Laboratory Staff (1954).

The evaluation of water quality was in accordance with regulatory standard. The approach ensured that the samples collected were tested in accordance with agreed requirements using competent personnel as well as appropriate equipment and materials. In-situ determinations (field Parameters) in groundwater such as pH, Electrical conductivity and temperature were determined on the field due to their unstable nature.

The Sodium Adsorption Ratio (SAR) was determined using the fomula below:

$$SAR = \frac{Na^{+}}{\sqrt{\left(\frac{Mg^{2+} + Ca^{2+}}{2}\right)}} \qquad \text{-------------------------- (1)}$$

Where the values of sodium, calcium and magnesium are in miliequivalent per litre. The miliequivalent values of the various ions are shown in Table 4.

RESULTS AND DISCUSSION

The water used for drinking purposes should be free from turbidity, colour and micro-organisms (Karanth, 1989). Chemically, the water should be soft with less dissolved solids and free from poisonous constituents and should be within certain limits. To ascertain the suitability of groundwater for drinking, hydro-geochemical parameters of the study area were compared with the guidelines recommended by the World Health Organization (WHO, 2006). The results of the study therefore are discussed for both physical and chemical properties (Table 1) while Table 2 show the range in values of hydro-geochemical parameters compared with WHO (2006) quality regulation.

Physical Properties

The results of the physical properties are presented in Table 1. The temperature of the groundwater within the area of study ranges from 29.8^{0}C to 30.5^{0}C which indicates moderate value. There is no value of groundwater temperature recommended by World Health Organization (WHO, 2006), but the value obtained are moderate. The turbidity values range from 1.0mg/l to 15.0mg/l, while the Total Suspended Solid (TSS) is not stated in WHO (2006) guidelines but WHO (2004) stated 10mg/l as the desirable level of TSS and a maximum permissible limit of 25mg/l in drinking water. The highest value of TSS within the study area is 15.0mg/l which is below the maximum permissible limit when compared with the WHO guideline. The water could be useful for drinking and other domestic purposes. The low value of TSS shows that the water is free from pollutants and of good quality.

The electrical conductivity values range from 14.7µS/cm to 490µS/cm. the standard recommended by WHO (2006) is 500µS/cm. The parametric values of all the boreholes shows low values of electrical conductivity, which is an indication of low concentration of dissolve ions in the groundwater as well as low salinity.

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Table 1: Results of Physico-Chemical Parameters of Groundwater in the Study Area

Borehole S/No.	pH	Temperature (°C)	Conductivity (µS/cm)	TDS (mg/l)	Salinity (mg/l)	TSS (mg/l)	Hardness (mg/l)	SO_4 (mg/l)	Fe^{2+} (mg/l)	HCO_3 (mg/l)	mg^{2+} (mg/l)	Ca^{2+} (mg/l)	K^+ (mg/l)	Na^+ (mg/l)	Cl^- (mg/l)
AH_1	4.66	30.50	490.00	343	231.00	3.00	91.68	<0.01	<0.01	0.00	45.731	45.944	89.7568	0.118	23.50
AH_2	5.30	29.80	50.80	33.3	23.20	5.00	80.22	<0.01	3.207	2.00	50.102	30.113	43.5483	0.025	18.00
AH_3	5.44	30.10	14.70	11.10	6.00	15.00	69.91	<0.01	2.657	1.00	39.315	30.592	20.0936	0.101	<0.01
AH_4	5.79	29.80	48.80	35.00	22.40	6.00	91.09	<0.01	1.609	2.00	49.010	42.0766	39.4569	<0.01	5.00
AH_5	5.92	30.20	32.00	23.30	15.50	7.30	85.21	<0.01	1.698	3.00	47.101	38.112	20.0936	<0.01	4.75
AH_6	4.95	30.20	82.40	56.90	36.90	2.00	100.07	<0.01	1.975	2.00	65.022	35.001	39.4569	0.002	<0.01
AH_7	5.18	30.10	29.20	21.20	12.70	1.00	76.37	<0.01	1.295	0.00	43.110	33.255	21.0265	0.004	<0.01
AH_8	5.06	30.10	57.20	38.90	23.30	1.50	99.28	<0.01	2.245	8.00	59.121	40.000	46.7457	<0.01	2.00
AH_9	4.68	30.10	298.00	209	140.00	9.30	125.00	<0.01	4.311	4.00	65.395	60.011	39.8687	<0.01	30.00
AH_{10}	5.51	29.80	22.40	16.00	11.60	8.00	133.00	<0.01	2.661	1.00	71.219	62.40	17.9545	0.115	<0.01

Table 2: Range in Values of Hydro-geochemical Parameters Compared with WHO (2006) Quality Regulation

Parameters	**Range of Analyzed Parameters**	**WHO, 2006**
Temp °C	29.8-30.50	NS
p^H	4.66-5.92	6.5-8.5
Conductivity (µS/cm)	14.70-490	500
TDS (mg/l)	11.10-343	500
Hardness as ($CaC0_3$)	69.91-133.0	500
Cl^- (mg/l)	<0.01-30.0	250
SO_4^{2-} (mg/l)	<0.01	250
Fe^{2+} (mg/l)	<0.01-4.311	0.3
Salinity (mg/l)	6.00-231	NS
HCO_3^-(mg/l)	0-8	NS
Ca^{2+} (mg/l)	30.113-62.40	75
Mg^{2+} (mg/l)	39.315-71.219	50
K^+ (mg/l)	17.9545-89.7568	200
Na^+ (mg/l)	<0.01-0.118	200
TSS (mg/l)	1.0-15.0	NS

NS - Not stated; TSS – Total Suspended Solids

Chemical Properties

The p^H of the groundwater within the study area ranges from a minimum of 4.66 to a maximum of 5.92 with mean value of 5.25. The neutral state is ideal, but the WHO (2006) stipulates a range of 6.5 – 8.5. The values of p^H of all the boreholes sampled showed that they are all acidic and do not meet the WHO (2006) acceptable standard. These water samples have the tendency of corroding metallic pipes and accessories.

The acidity of groundwater within the delta have been attributed to frequent flaring of gas which releases high amount of carbon dioxide into the atmosphere to react with precipitation and then falls to the earth as acid rain (Udom *et al* 1998, 1999, 2002; Nwankwoala, 2013).The acidity of the groundwater within the study area is also in accordance with the findings and results of (Etu-Efeotor, 1981; Etu-Efeotor and Odigi, 1983; Amajor, 1986, Etu-Efeotor and Akpokodje, 1990; Amadi and Amadi, 1990; Udom *et al*., 1990; Nwankwoala and Udom, 2011b).

Total Dissolved Solid (TDS) ranges between 11.10mg/l to 343mg/l. The WHO (2006) recommended value is 500mg/l. In comparison, it shows that the groundwater contain low Total Dissolved Solids (TDS) as it falls below WHO value. This implies that the groundwater within the study area is fresh. The values of the groundwater hardness range from 69.9 – 133.0, which is equivalent to 0.076 – 0.133 mg/l $CaCO_3$. This, when converted gave the following: AH_1 = 0.092mg/l, AH_2 = 0.08mg/l, AH_3 = 0.07mg/l, AH_4 = 0.09mg/l, AH_5 = 0.085, AH_6 = 0.100mg/l, AH_7 = 0.076mg/l, AH_8 = 0.0mg/l, AH_9 = 0.125mg/l and AH_{10} = 0.133mg/l, respectively. The hardness of water is attributed to the presence of divalent metallic cations, the most abundant of which are magnesium and calcium, though some proportions of iron may be present. Salinity indicates the percentages of

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dissolve salts. It ranges from 6.0mg/l to 231mg/l. The WHO (2006) guidelines do not state any value for salinity but the value obtained is low.

From the WHO (2006) standard, a hardness value of 500mg/l is the maximum permissible value but all the boreholes sampled were below 500mg/l, indicating very soft water. The concentrations of sodium range from <0.002 – 0.118mg/l. All the boreholes sampled recorded low concentration of sodium, which is also in accordance with Todd (1980), who stated that the concentration of sodium in groundwater is commonly less than 100mg/l. The concentration of sodium in drinking water depends on several factors such as the hydro-geological conditions, the season of the year and industrial activities (Rivers State Water Board (2002). Sodium in drinking water could be increased during treatment, particularly during water softening processes. Within the Niger Delta, sodium in the water probably owe it source from dissolution of clay minerals particularly feldspar which has sodium in its structure. The values of chloride ion in the groundwater within the study area is low and ranges from <0.01 – 30.00mg/l. WHO (2006) guideline stated 250mg/l, WHO (2004) recommended 100mg/l, while WHO (2006) recommend 200mg/l and maximum permissible limit of 600mg/l in drinking water.

Todd (1980), Udom *et al.,* (1998) and Nwankwoala (2013) suggested that chloride content greater than 40mg/l in the coastal aquifer indicates saltwater contamination while Lusczynski and Swarzenski (1966) considered chloride above 50mg/l as an indication of salt water intrusion. However, in this study, the maximum chloride content of 30.00mg/l was obtained which implies that there is no salt water intrusion. The groundwater is safe for drinking as well as for industrial purposes due to its low sodium and chloride content. Excess of chloride imparts a salty taste and may cause physiological damages to the health of humans (Todd, 1980).

The concentrations of HCO_3^- range from 0 – 8mg/l. The value of HCO_3^- is not stated in the WHO (2006) guideline. However, the WHO (2004) standard for drinking water is 120mg/l. The concentration of sulphate within the study area is very low, less than 0.01mg/l in all the samples obtained. When compared with the WHO (2006) guideline value of 250mg/l the sulphate level is insignificant. The sulphate level agrees with the findings of Udom and Nwankwoala (2011b). The low values are most probably due to the removal of SO_4^{2-} by the actions of bacteria (Amadi *et al.,* 1989). The low concentration of sulphate suggests absence of any abuse of the water by leakage from septic tanks in the area. Although, ingesting water containing high concentration of sulphate can have laxative effective, which is enhanced when the sulphate is consumed in combination with magnesium (Rivers State Water Board, 2002). In addition, metal corrosion may be increased by high sulphate level. The presence of sulphate in groundwater is thought to come from dissolution of gypsum, anhydrite and oxidation of some sulphate minerals such as pyrite and also from combustion of fuels.

The detected values of magnesium in the samples range from 39.315 – 71.219mg/l with a mean value of 52.6mg/l. The WHO (2006), guideline recommended 50mg/l. From the foregoing, AH_1, AH_2, AH_3, AH_4,

AH_7 are below the value while AH_6, AH_8, AH_9 and AH_{10} are above 50mg/l as shown in Fig. 2 - 7. A high concentration of magnesium has laxative effect, most especially on new user of the water supply.

Groundwater samples indicate a calcium value ranging from 30.113 – 62.401mg/l with a mean value of 41.75mg/l (Tables 1 & 2). The concentrations of the various parameters are shown in Figures 2 – 7.

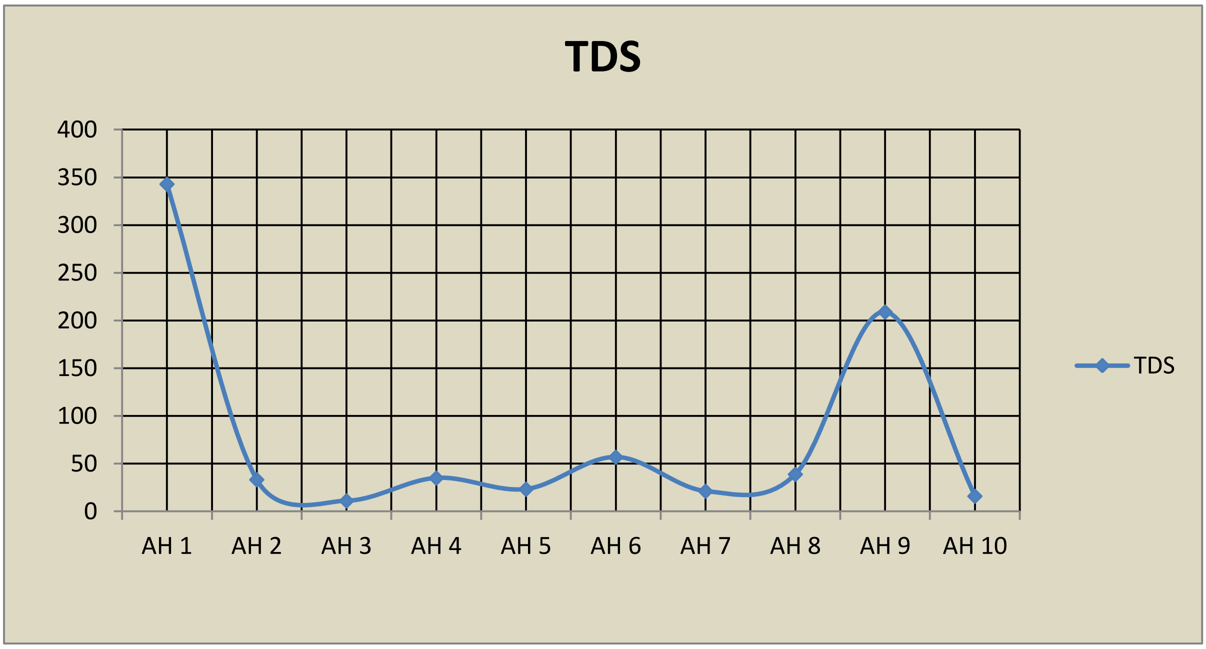

Fig. 2: TDS concentration of borehole water samples

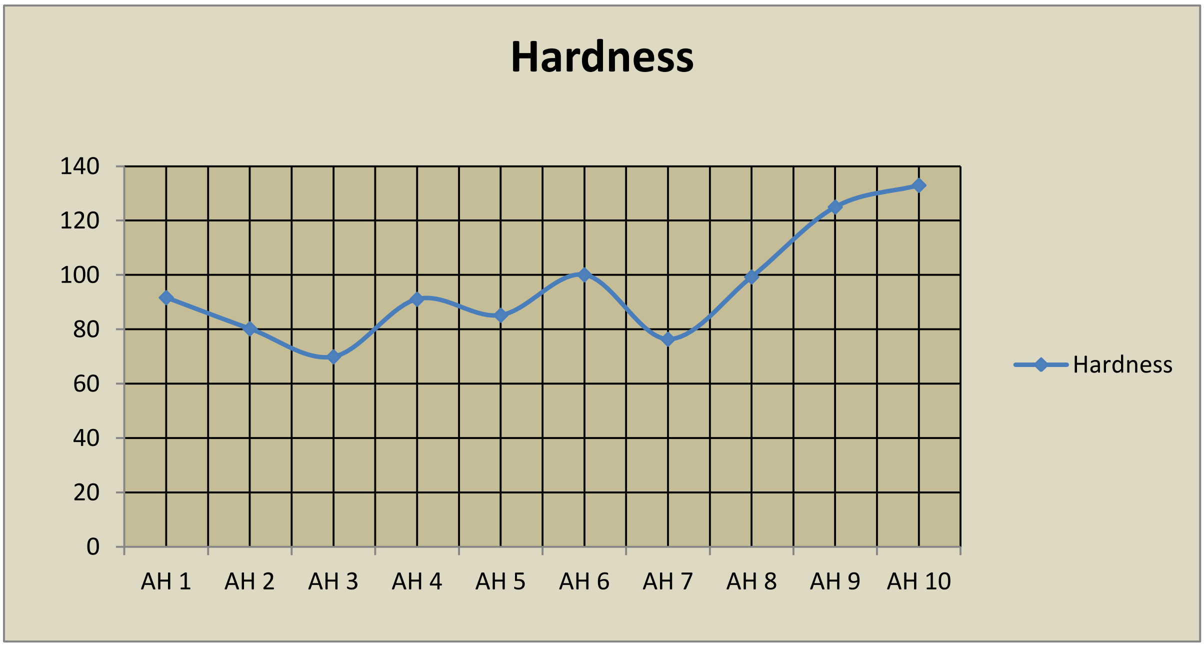

Fig. 3: Hardness Concentration of borehole water samples

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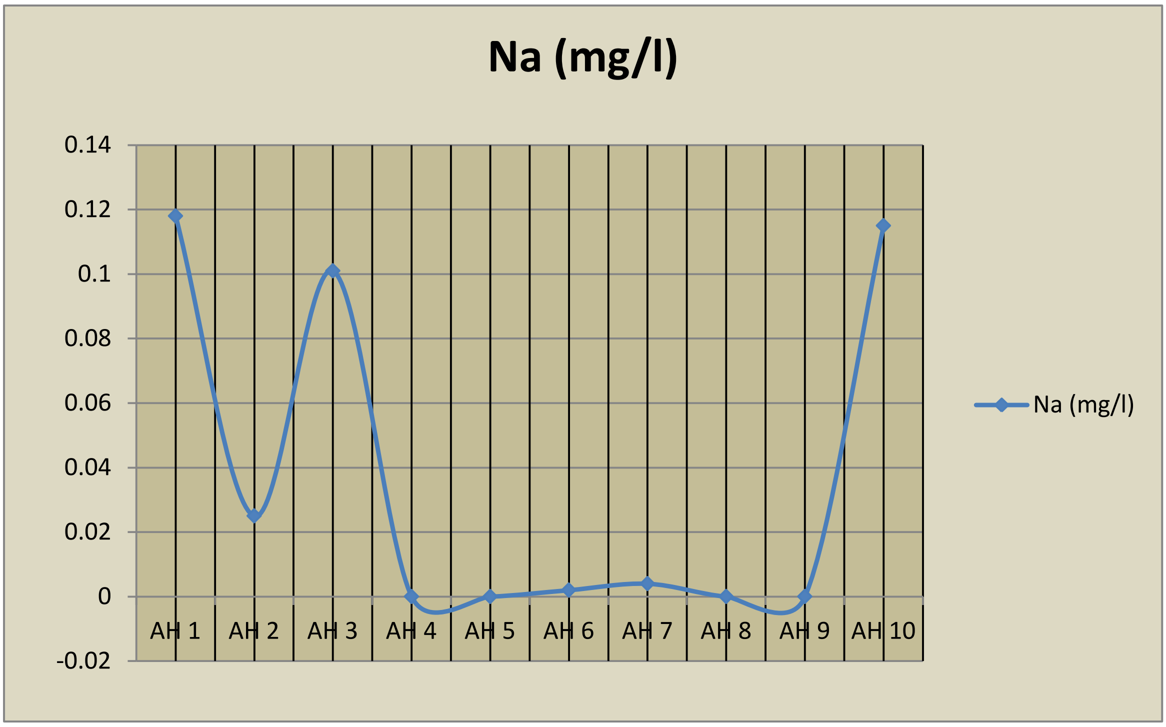

Fig. 4: Sodium (Na) concentrations in the boreholes

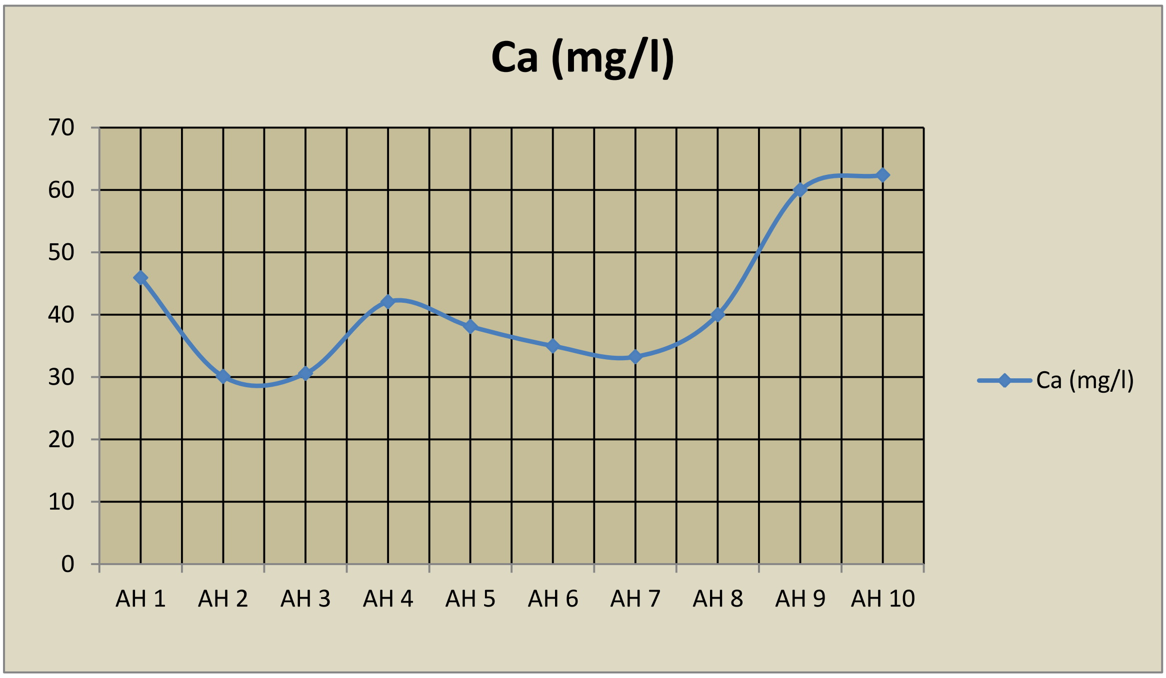

Fig. 5: Calcium (Ca) concentrations in the borehole samples

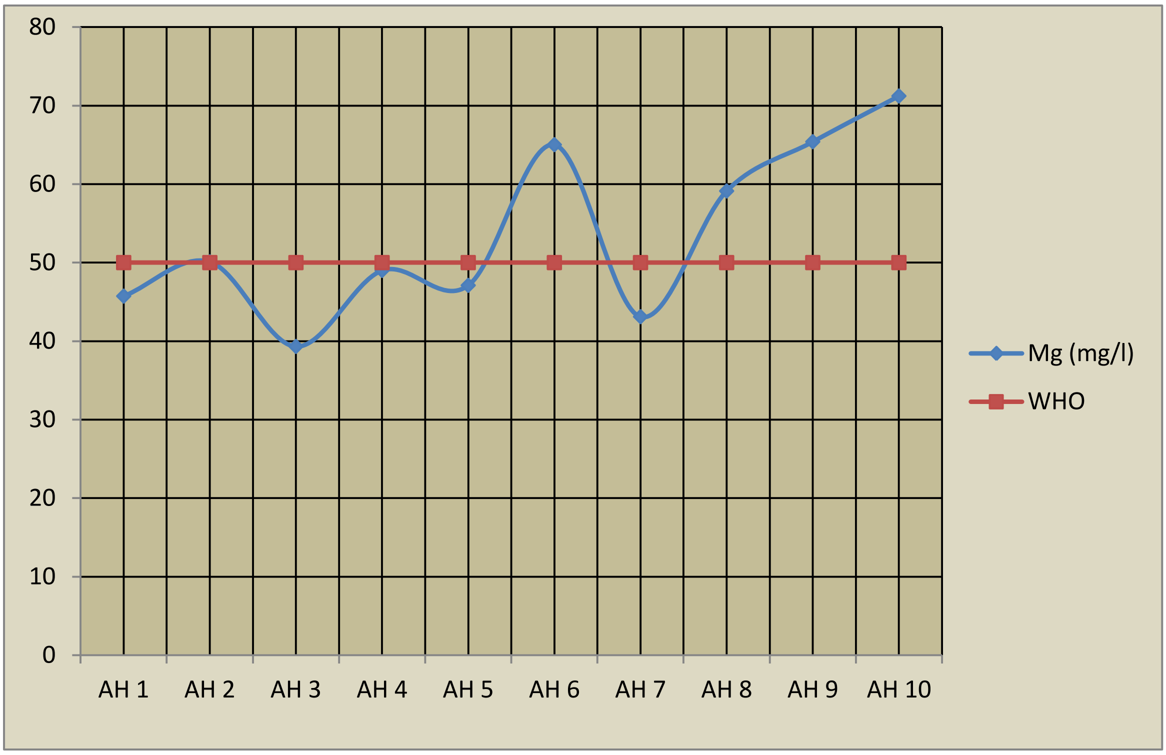

Fig. 6: Magnesium concentrations of borehole samples.

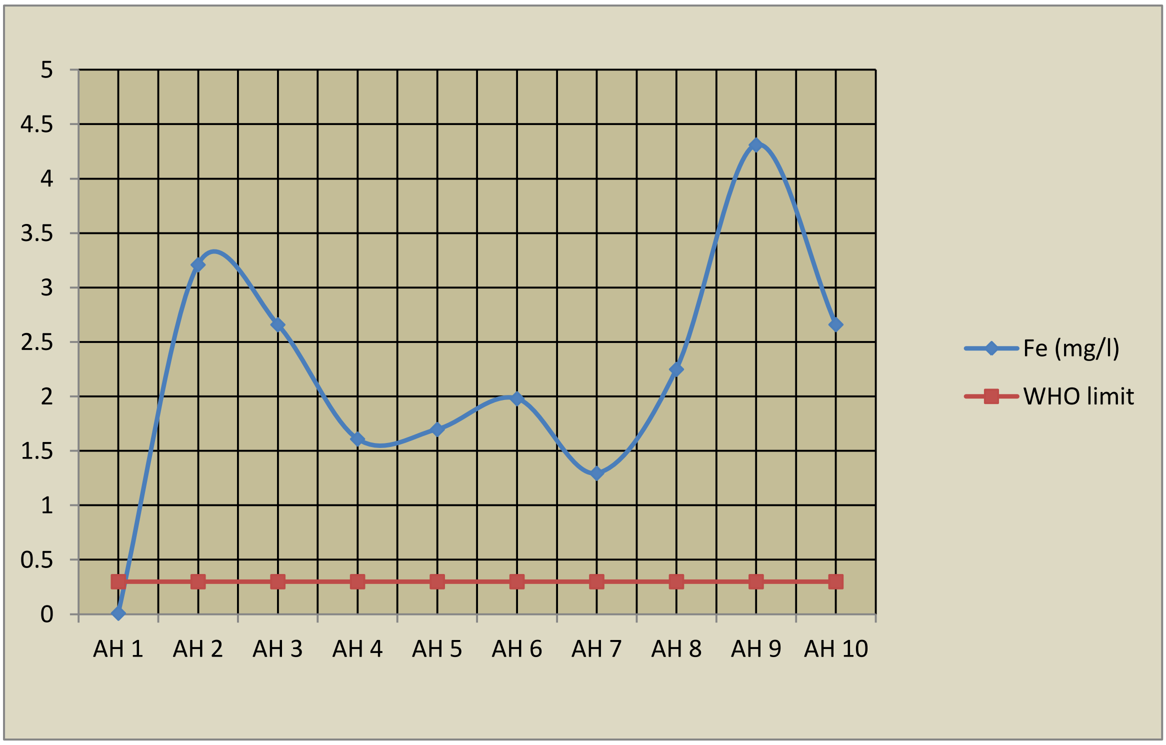

Fig. 7: Iron concentration compared with WHO (2006)

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Suitability for Irrigation Use

Sodium Adsorption Ratio (SAR) values below 10meq/L are considered low (Johnson 1975). A high value of sodium may displace magnesium and calcium ion leading to a reduction in permeability and poor soil drainage. High values of SAR have hazardous implications and can damage the structure of the soil while its low value is considered good for irrigation.Richard (1954) classified the concentration of soluble salt in irrigation water (salinity hazard) into four classes on the basis of electrical conductivity (EC) and SAR (sodium hazard).

The different classes of salinity hazard include Low C1 (EC< 250 µS/cm), medium C2 (EC 250 - 750µS/cm), high C3 (EC 750-2250µS/cm); and very high C4 (EC > 2250 µS/cm). The sodium hazard classes include Low S1 (SAR<10), medium S2 (SAR 10-18); high S3 (SAR 18-26), and very high S4 (SAR > 26). The SAR values within the study area range from 4.619meq/l - 2.36meq/l (Table 3).From the above, it could be deduced that from the calculated value of SAR, the water could be classified as class S1 due to low salinity and low sodium water. This further reveals and attests to the fact that the water is good for irrigation.

Table 3: Calculated SAR values

Borehole S/No.	**SAR (Meq/L)**	**Remarks**
AH_1	2.950	Good
AH_2	6.435	Good
AH_3	2.848	Good
AH_4	2.484	Good
AH_5	2.560	Good
AH_6	4.619	Good
AH_7	1.079	Good
AH_8	2.349	Good
AH_9	2.126	Good
AH_{10}	2.362	Good

Results of this study showed that the water is soft and suitable for drinking and other domestic activities as well as agricultural purposes due to the low SAR values. Mild treatment for some parameters is required for its usage. There commendations that can be useful in salvaging the groundwater within the study area and its effects on human and material resources include (a) The groundwater within the study area is acidic hence PVC pipes should be used during construction of boreholes to resist corrosion (b) Continuous monitoring of groundwater quality is essential in order to supply potable water and to curtail any abuse in the future (c) Due to rapid urbanization and indiscriminate dumping of waste, laws and proper pollution control measures should be put in place (d) Proper documentation of hydro-geological information on the study area should be carried out to enable easy literature review in the future, and (e) Water for industrial purposes should be treated according to industrial requirements.

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