Groundwater Level Distribution and Evaluation of Physicochemical Characteristics in North-Eastern Bayelsa State, Nigeria

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ABSTRACT

This research involves the analysis of the spatial distribution of groundwater level, and the evaluation of its physicochemical characteristics in the north-eastern Bayelsa State in Nigeria. The study area is located between latitudes $4^o12'$ and $5^o23'$N and longitudes $5^o22'$ and $6^o45'$E. The samples locations were geo-referenced and the elevations of the locations also determined using global positioning system (GPS). 12 randomly-selected groundwater sample borehole locations were used from where the water samples were collected for the physicochemical analysis. The evaluation of water quality was in accordance with regulatory standard. The water samples from boreholes were subjected to physicochemical analysis and results were compared to the World Health Organization Standard (WHO) to determine its suitability for domestic and industrial uses. The surface atmospheric temperature in the area of study ranged between 26.2 and 28.6^oC. The groundwater level (depth to groundwater surface) ranges between 0.4 and 2.6m with an average of 1.60m. The depth to groundwater was observed to increase with increase in elevation, being shallower southwards towards the sea. Elevation varies between 6.0 and 16.0m with an average of 10.8m. Elevations are greatest in the upland recharge areas where groundwater levels are deepest. Groundwater-levels at lower elevations are near valley bottoms, which are groundwater discharge areas. pH value ranged between and 5.80 and 7.20 with an average value of 6.70. However all the samples met the WHO standard for drinking water which is between 6.5 and 8.5. In this investigation, the mean total dissolved solid (TDS) was 357.25mg/l. In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. Electrical conductivity (EC), a measure of water's capacity to convey an electric current, has values ranging from 260µs/cm to 1357 µs/cm with an average value of 697.0 µs/cm. Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials; which shows an average concentration of 3.96mg/l. Bicarbonate shows an average concentration of 48.03gm/l. Carbonate also shows an average concentration of 3.93mg/l. Nitrate average concentration was 0.298mg/l. Sulphate mean concentration value was 14.05mg/l. Chloride shows a mean concentration value of 34.18mg/l. From the results, the mean concentration values of Sodium, Potassium, Magnesium, Calcium and Iron are well within the permissive and tolerable range of the international (WHO) standard.

Index Terms: Groundwater, Aquifer, Physicochemical, TDS, BOD, EDTA, Contamination, Niger Delta

1. INTRODUCTION

Groundwater resources are influenced by both climate change and human activities ([1], [2]). For example, climate change has resulted in increasing global atmospheric temperatures, and has led to a modified precipitation pattern, which may have a direct impact on groundwater levels [3]. Previous studies investigating the response of groundwater systems to climate change have achieved considerable success ([4], [5], [6]). It has been shown that groundwater systems have undergone changes due to human activities, including groundwater abstraction and reservoir construction. Since 1960, access to pumped wells has caused a rapid worldwide increase in groundwater development for municipal, industrial, and agricultural purposes [6].

The combination of climate change and indiscriminate groundwater development has caused a general decline in groundwater levels, resulting in the depletion of groundwater, land subsidence, and saltwater intrusion in deltaic areas [7]. Lower groundwater levels are a threat to the environment and hinder economic development. Excessive groundwater depletion has affected vast regions, including Northwest India, North China, and the Central USA [8]. Thus, it is important to understand the evolution of groundwater systems, and the dual effects of climate change and anthropogenic activities.

Groundwater is the water present beneath the Earth surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Over ninety percent of fresh water available at any given moment on the earth lies beneath the land surface as underground water. In the Niger Delta area, quite a lot of works have been done on groundwater studies by some researchers including Geological Society of Nigeria [GSN] ([9], [10]). Groundwater is not just any water below the ground surface but water found in rocks that are permeable enough to permit reasonable quantity of water to yield into wells.

Groundwater is directly related to human existence and to the sustainable development of a society, because it plays an important role as a water resource. More than two billion people worldwide depend on groundwater for their daily water supply, and a large proportion of the world's agricultural and industrial water requirements are supplied by groundwater [11]. Due to an increasing demand for groundwater in response to rapidly growing urban, industrial, and agricultural water requirements, several countries, especially those in arid and semi-arid zones, are experiencing water shortages resulting from the imbalance between demand and supply [12]. In this work, ground water levels in the north-eastern part of Bayelsa State, Nigeria are measured. Most of the borehole water samples are analysized for contamination. Knowledge of the distribution and nature of physicochemical properties can be used for proper planning for development or management of groundwater supplies in the study area and environs.

2. HYDROGEOLOGIC SETTING OF THE STUDY AREA

The state is geographically located within latitude 4°15′ North and latitude 5°23′ North. It is also within longitudes 5°22′ East and 6°45′ East (Figure 1). The state is bounded by Delta State on the north, Rivers State on the east and the Atlantic Ocean on the western and southern parts.

The geology of Bayelsa State in the Niger Delta has been reported by several workers ([13], [14], [15]). Bayelsa State is located within the lower Niger Delta Plain believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. The major geological characteristic of the state is sedimentary alluvium. The entire state is formed of abandoned beach ridges and due to many tributaries of the River Niger in this plain, considerable geological changes still abound.

The major soil types in the state are young, shallow, poorly drained soils and acid sulphate soils. There are variations in the soils of Bayelsa State [16]. Some soil types occupy extensive areas whereas others are of limited extent. However, based on physiographic differences, several soil units could be identified in the State. These include: The soils of the high-lying levees e.g. sandy loam, loamy sand, and silty loam soils as well as sands; The soils of the low-lying leaves e.g. the moderately fine texture, red silty or clay loamy soils; The meander belt soils which differ only slightly from the soils of the levels. he silted river belt soils e.g. peat for clay water bogged soils found mainly in the beds of dead creeks and streams; The basin soils e.g. silky clay loam or sandy loam which are inundated by water for most of the year; The transition zone soils e.g. silt and sandy silt which are known to be under the daily influence of tidal floods and fresh waters. There are pockets of potash deficiency especially in the sandy soils. The texture of most soils ranges from fine to medium grains.

Generally, Bayelsa State is a lowland state characterized by tidal flats and coastal beaches, beach ridge barriers and flood plains. The net features such as cliffs and lagoons are the dominant relief features of the state. The fact that the state lies between the upper and lower Delta plain of the Niger Delta suggests a low-lying relief. The broad plain is gentle-sloping. The height or elevation decreases downstream. Rainfall in Bayelsa State varies in quantity from one area to another. The state experiences equatorial type of climate in the southern the most part and tropical rain towards the northern parts. Rain occurs generally every month of the year with heavy downpour ([17], [18]). The state experiences high rainfall but this decrease from south to north. Akassa town in the state has the highest rainfall record in Nigeria. The climate is tropical i.e. wet and the dry season.

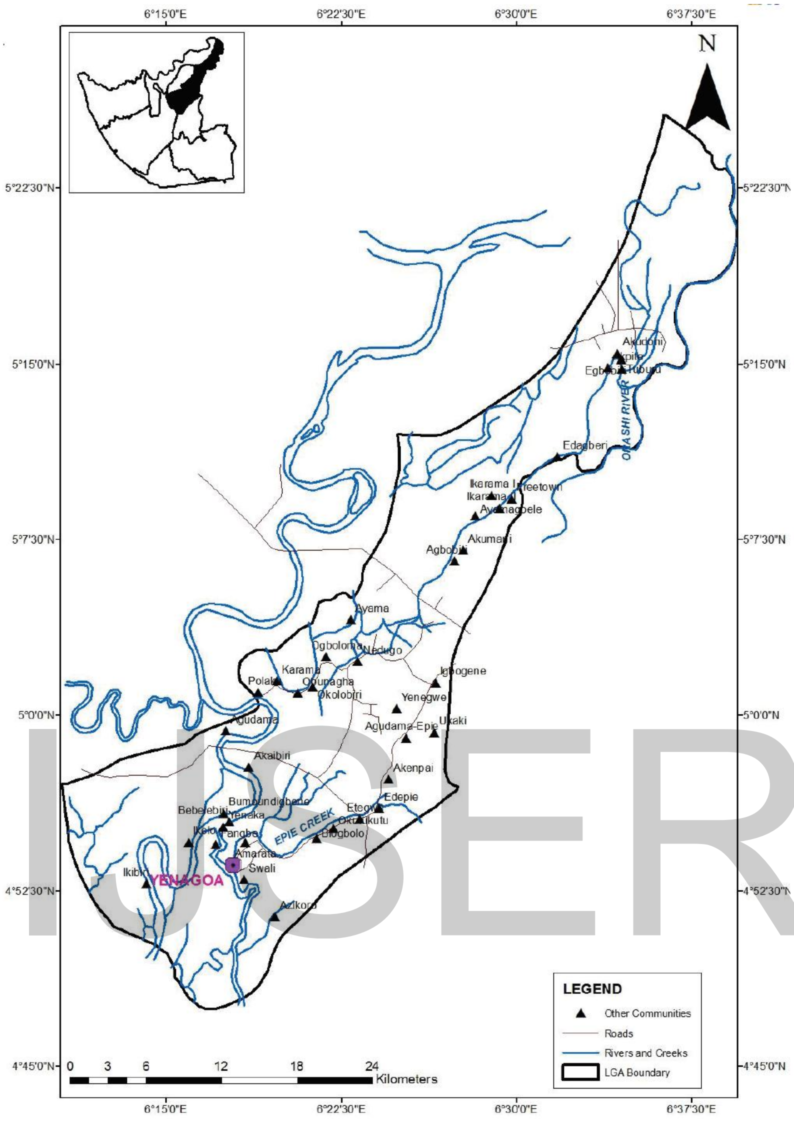

Figure 1: Geological Map of the Study Area

The mean monthly temperature is in the range are of 25°C to 31°C. Mean maximum monthly temperatures range from 26°C to 31°C. The mean annual temperature is uniform for the entire Bayelsa State. The hottest months are December to April. The difference between the wet season and dry season on temperatures is about 2°C at the most. Relative humidity is high in the state throughout the year and decreases slightly in the dry season ([19], [20]). Like any other state in the Niger Delta, the vegetation of Bayelsa State is composed of four ecological logical zones. These include: coastal barrier island forests, mangrove forests, freshwater swamp e.g. forests and lowland rain forests. These different vegetation types are associated with the various soil units in the area, and they constitute part of the complex Niger Delta ecosystems. Parts of the fresh water swamp forests in the state constitute the home of several threatened and even endangered plant and animal species [21].

There are coastal barrier highland forests and mangrove forests. Coastal barrier highland forest vegetation is restricted to the narrow ridges along the coast. This vegetation belt is characterised by low salinity-tolerant fresh water plants. Sometimes of the Avicinia species of mangroves prevail in this vegetation. Palms such as phoenix reclivata and other species such as Uapacia, Xylopia and land Taminalia are predominant. In this belt, commercial timber species are found. The mangrove vegetation of the state is usually found between mid-tide relief levels to extreme high-water mark. This vegetation linked with the brackish swamps which form a maze of water courses and highlands affected by the ebb and flow of tides.

The area lies within the humid equatorial tropical climate zone due to its proximity with the Gulf of Guinea. This area has its wet season from April to October, while dry reason lasts from November to March. Geologically, the entire site and the environs lie within freshwater zone of the Niger Delta and they are of Miocene era. This zone is generally known to be characterized by conservable thickness of greyish salty-clay/mostly active) with intercalation of coastal plain and of the Benin geologic formation. Benin formation is the most recent of the three lithostratigaphic units (i.e. Benin, Agbada and Akata formations) of the Niger Delta. The coastal plain sand itself is overlain by various Quaternary deposits.

3. MATERIALS AND METHODS

Twelve boreholes were used to achieve the aim of this work from which the water samples were collected. The samples were collected with well washed and sterilized containers after 10 minutes of pumping to ensure that the samples were stirred-up and are the true representative from the aquifers. After the collection of the samples, the containers were covered with black polyethylene bags to avoid photolytic effect on the original sample content and were stored in coolers with regulated temperature of about $4^{o}C$; then transported to the laboratory for the analyses.

The pH, temperature and electrical conductivity parameters of the samples were determined in the field at the point of collection of the samples with appropriate instruments of measurement; the pH was measured with a pH-Meter, the temperatures were measured with Mercury Thermometer and the electrical conductivities were measured with a Mark Electronic Switchgear Conductivity Meter. All analyses were carried out at a Standard Laboratory using International Regulatory Methods ([22], [23]).

The water samples were taken from randomly selected boreholes in the study area indicated by the sample numbers and the location names as; BH 1 (Gbarantoru-2), BH 2 (Igbedi East-3), BH 3 (Igbedi West-2), BH 4 (Agudama), BH 5 (Kiama), BH 6 (Ndu-Newsite), BH 7 (Ndu-Ogobiri-1), BH 8 (Ndu-Tombia-4), BH 9 (Odi-1), BH 10 (Ogbia), BH 11 (Ogobiri-3), and BH 12 (Oopume). The sample locations were geo-referenced showing the locations elevations and the coordinate as presented by Table 1.

The analyses was done on the samples to evaluate ; Acidity (pH), Total Dissolved Solids (TDS), Electrical Conductivity (EC), Biochemical Oxygen Demand (BOD), Bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), Nitrate (NO_3^-), Sulphate (SO_4^{2-}), Chlorine (Cl^-), Sodium (Na^+), Potassium (K^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), and Iron (Fe^{2+}). The analytical results are presented in Table 2.

4. RESULTS AND DISCUSSION

4.1. Results

The results from the work are presented in Tables 1 and 2, and Figures 2 – 18.

Table 1: Groundsurface Elevation and Groundwater Level for the Study Area

Name of Borehole Location	Borehole Number	Groundsurface Elevation (m)	Groundwater Level (m)	Latitude	Longitude	Eastings	Northings
Gbarantoru-2	BH1	11.3	1.2	4.98718	6.30535	798829	551858
Igbedi East-3	BH2	9.6	1.6	4.97865	6.18092	812642	550972
Igbedi West-2	BH3	11.3	1.5	4.98194	6.2246	807793	551316
Agudama	BH4	8.0	1.5	5.00316	6.25216	804724	553651
Kiama	BH5	16.0	1.9	5.11484	6.30677	798613	565985
Ndu-Newsite	BH6	11.0	1.7	4.98893	6.11246	820236	552143
Ndu-Ogobiri-1	BH7	14.0	1.2	4.98253	6.11365	820107	551434
Ndu-Tombia-4	BH8	12.6	1.2	4.98556	6.14714	816389	551753
Odi-1	BH9	11.5	2.2	5.18415	6.29764	799593	573659
Ogbia	BH10	11.7	1.9	4.68844	6.35271	793702	518780
Ogobiri-3	BH11	13.0	1.1	4.99841	6.121473	819231	553188
Oopume	BH12	8.0	2.3	4.6681	6.3589	793023	516527
Opokuma	BH13	6.0	2.4	5.10713	6.31923	797234	565126
Otuoke-1	BH14	9.0	2.3	4.82031	6.33907	795160	533378
Sagbama	BH15	11.0	1.8	5.157	6.2085	809496	570697
Sagbama-1	BH16	12.5	2.6	5.12145	6.18154	812505	566776
Sagbama-3	BH17	11.0	1.5	5.1741	6.21998	808214	572584
Sampo	BH18	10.0	1.0	5.13003	6.35465	793293	567643
Tantuama-Ndu	BH19	10.0	0.4	4.97115	6.08648	823129	550188
Tombia	BH20	9.5	1.3	4.99594	6.26712	803067	552845
Yenagoa East	BH21	9.3	1.2	4.95439	6.43379	784590	548173
Yenagoa East-3	BH22	8.0	2.1	4.99869	6.41107	787092	553085
Yenagoa North-2	BH23	11.0	2.3	5.07214	6.41498	786626	561210
Yenagoa West-1	BH24	13.5	1.3	4.99787	6.3397	795012	553026
Yenagoa-1	BH25	9.0	1.4	4.9431	6.3435	794615	546963
Yenagoa-7	BH26	13.0	0.6	5.03406	6.39171	789224	557007

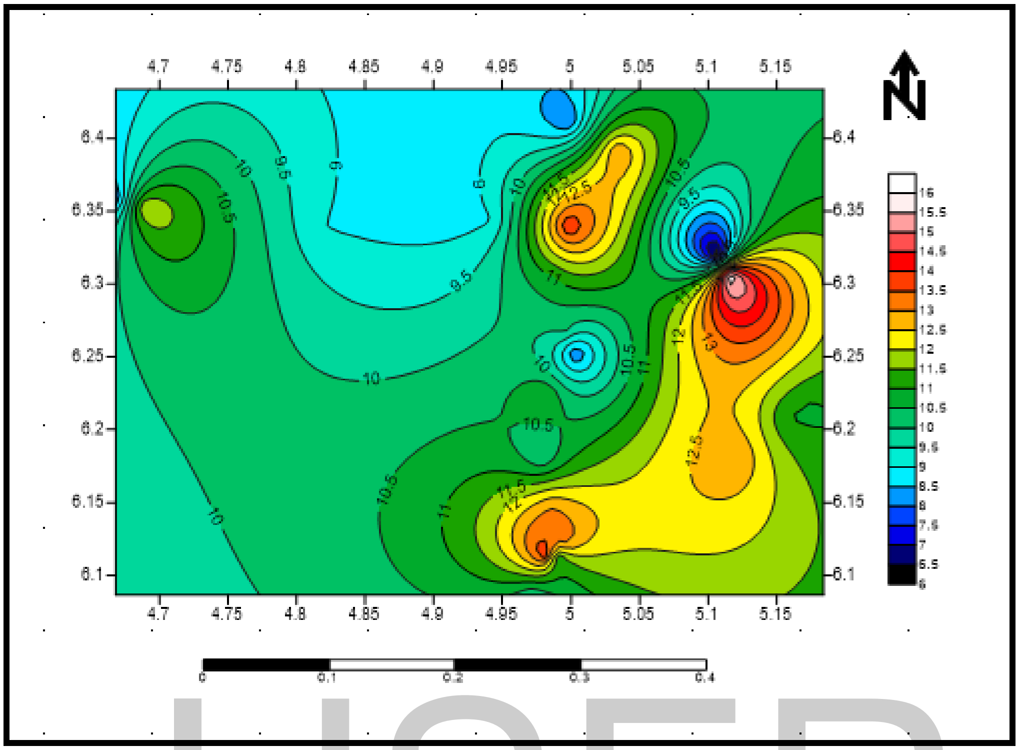

Figure 2: Groundsurface Elevation Contour Map of the Study Area

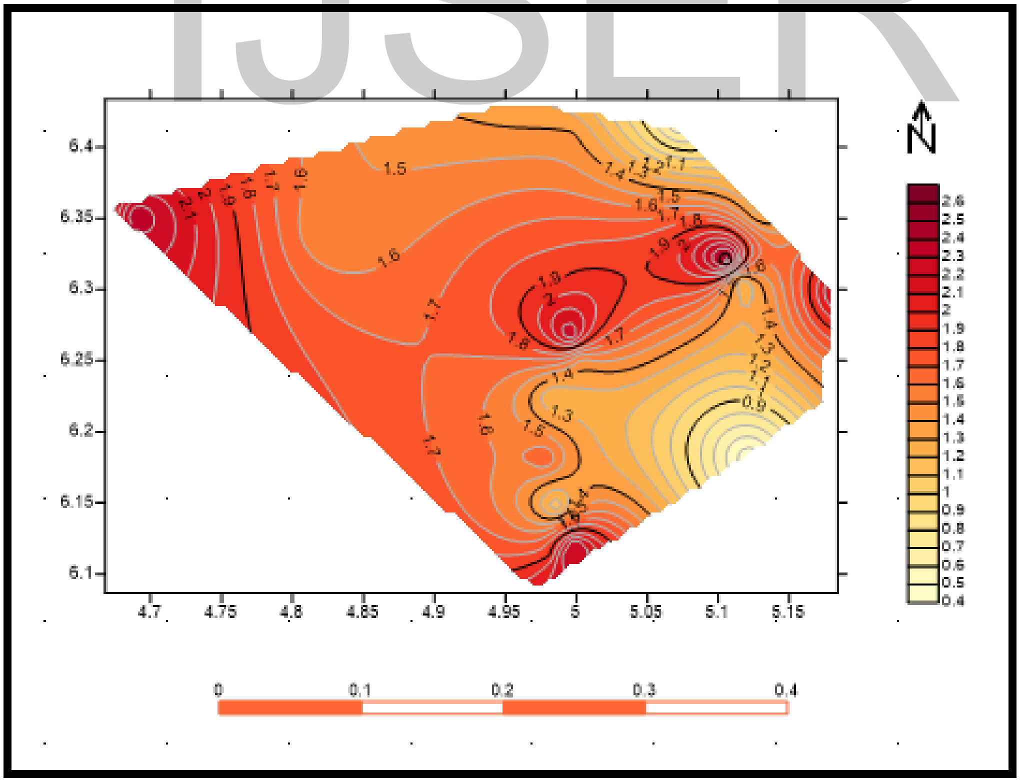

Figure 3: Groundwater Levels in the Study Area

Table 2: Physicochemical Parameters of Groundwater in the Study Area

Borehole Number	Temp (°C)	PH	TDS (mg/l)	EC (µS/cm)	BOD (mg/l)	HCO_3^- (mg/l)	CO_3^{2-} (mg/l)	NO_3^- (mg/l)	SO_4^{2-} (mg/l)	Cl^- (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	Fe^{2+} (mg/l)
BH1	28.6	6.5	182	367	2.6	68.4	4.8	0.42	7.0	22.1	17.3	5.1	10.9	26.8	0.21
BH2	28.7	6.8	562	1123	6.8	87.6	5.1	0.25	14.0	31.4	39.5	16.5	45.8	76.5	0.37
BH3	27.9	6.4	185	390	7.5	51.0	3.3	0.12	9.3	16.5	20.8	8.9	18.6	43.2	0.13
BH4	26.5	5.8	607	1206	5.1	42.5	BDL	0.35	18.2	43.7	52.0	21.2	54.0	48.3	0.54
BH5	28.2	7.2	284	569	0.7	18.2	5.1	0.40	11.7	32.5	20.6	17.4	42.5	56.2	0.28
BH6	27.4	7.1	676	1357	5.4	65.0	4.5	0.52	31.6	61.8	55.2	14.8	35.0	63.7	0.25
BH9	27.6	6.8	392	784	3.2	58.0	2.8	0.18	20.7	50.4	43.2	10.1	23.6	39.5	0.92
BH10	28.2	6.6	236	472	2.3	43.6	2.4	0.41	9.3	17.8	24.4	6.7	14.3	42.5	0.28
BH16	27.5	6.9	232	463	4.5	15.3	1.8	0.18	8.7	49.3	20.5	8.3	23.7	51.0	0.16
BH22	26.5	6.8	504	1010	1.3	69.4	6.3	0.22	18.4	23.8	39.3	26.4	47.5	68.0	0.72
BH24	27.8	6.7	298	597	1.8	37.8	BDL	0.27	15.0	39.6	23.1	20.3	35.3	26.8	0.46
BH26	26.2	6.8	129	260	6.3	19.5	3.2	0.26	4.7	21.3	14.4	7.9	20.5	16.2	0.05
Mean	27.6	6.7	357.3	697.0	3.96	48.03	3.93	0.30	14.05	34.18	30.86	13.63	30.98	46.56	0.36
WHO, 2006	25.0	6.5-8.5	1000	500		-	500	50	250	250	200	200	50	75	0.30
NSDWQ, 2007		6.5-8.5	1000	-		-			-	-	-	-	0.20	-	0.30

BDL = Below detectable level; BOD = Biochemical Oxygen Demand; EC = Electrical Conductivity; TDS = Total Dissolved Solid

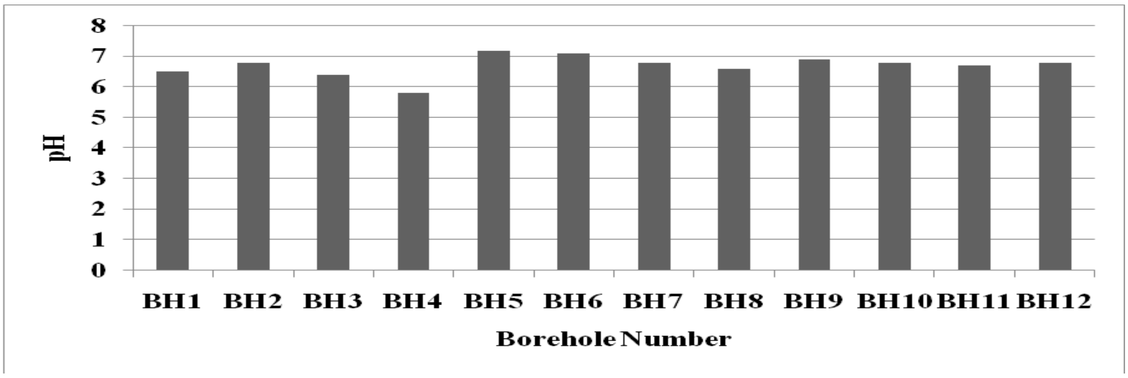

Figure 4: Chart showing variation of pH across boreholes

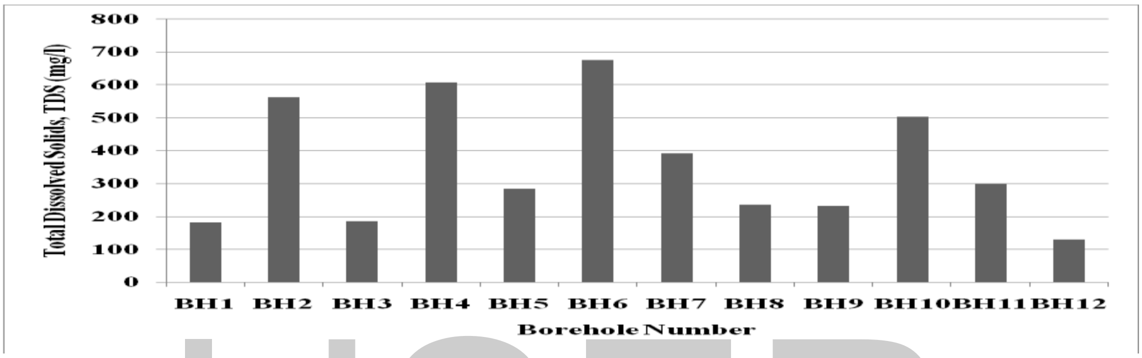

Figure 5: Chart showing variation of Total Dissolved Solids (TDS) across boreholes

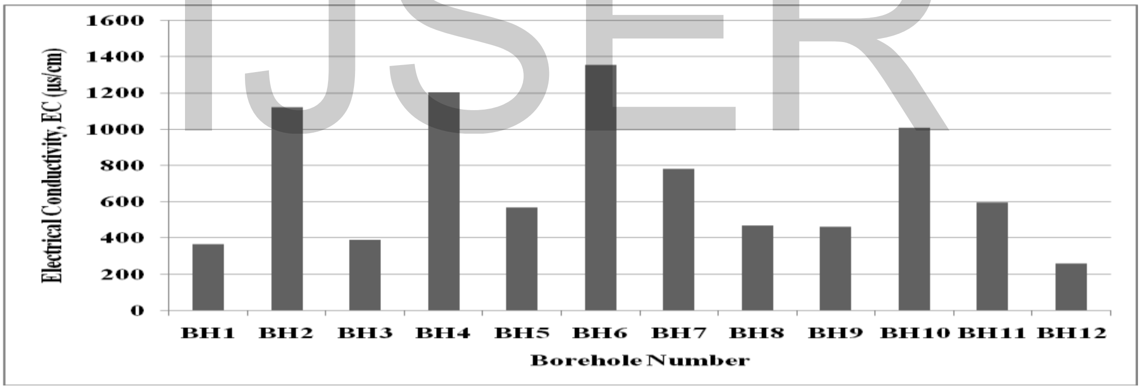

Figure 6: Chart showing variation of Electrical Conductivity (EC) across boreholes

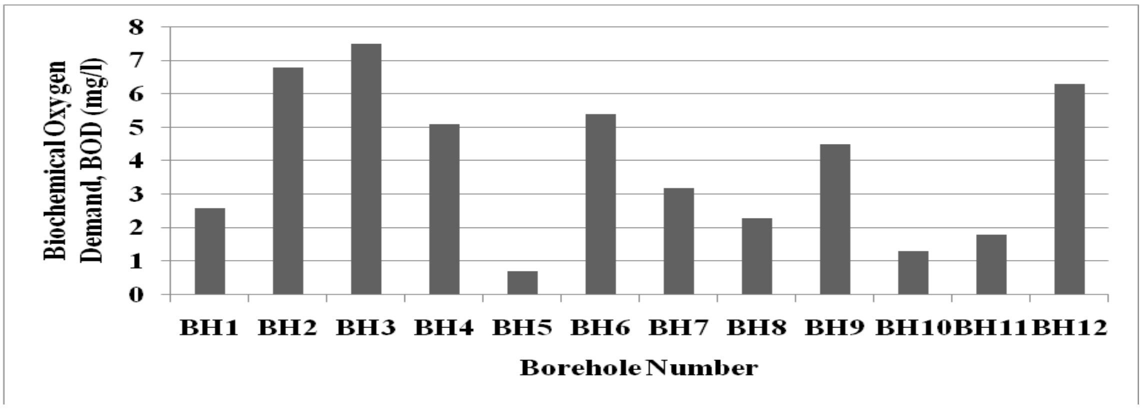

Figure 7: Chart showing variation of Biochemical Oxygen Demand (BOD) across boreholes

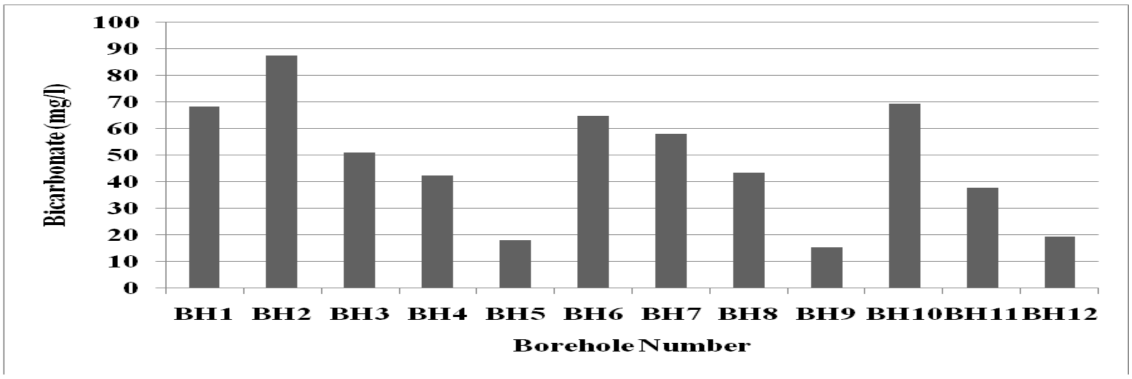

Figure 8: Chart showing variation of Bicarbonate across boreholes

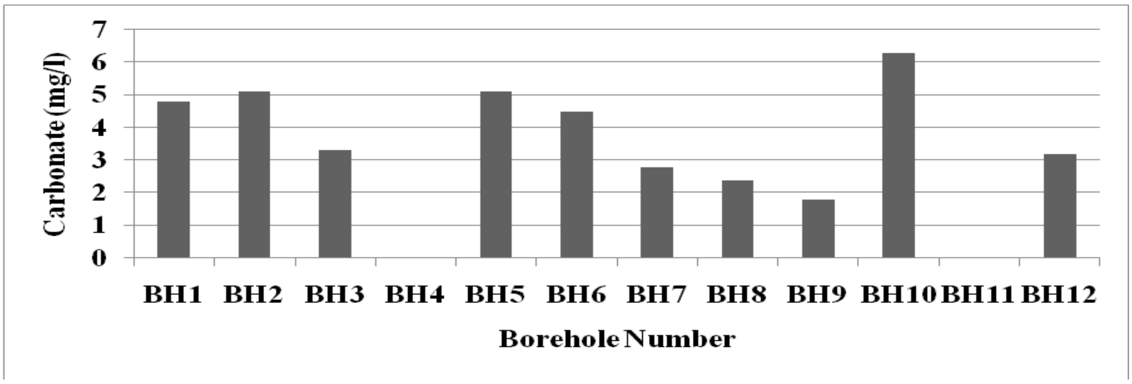

Figure 9: Chart showing variation of Carbonate across boreholes

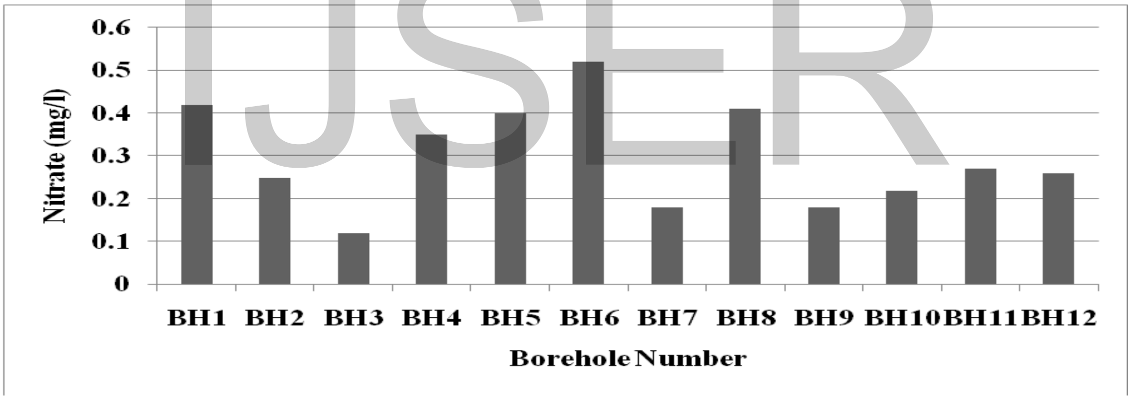

Figure 10: Chart showing variation of Nitrate across boreholes

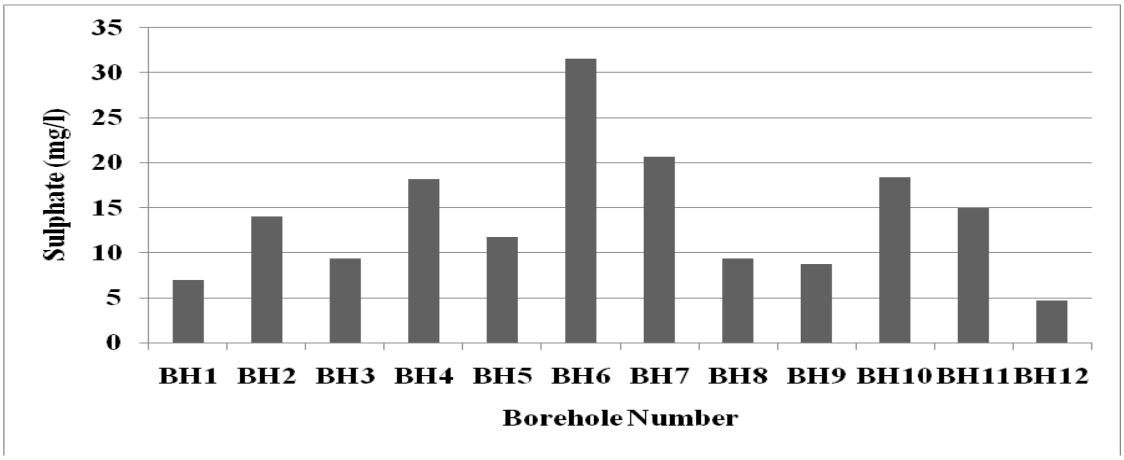

Figure 11: Chart showing variation of Sulphate across boreholes

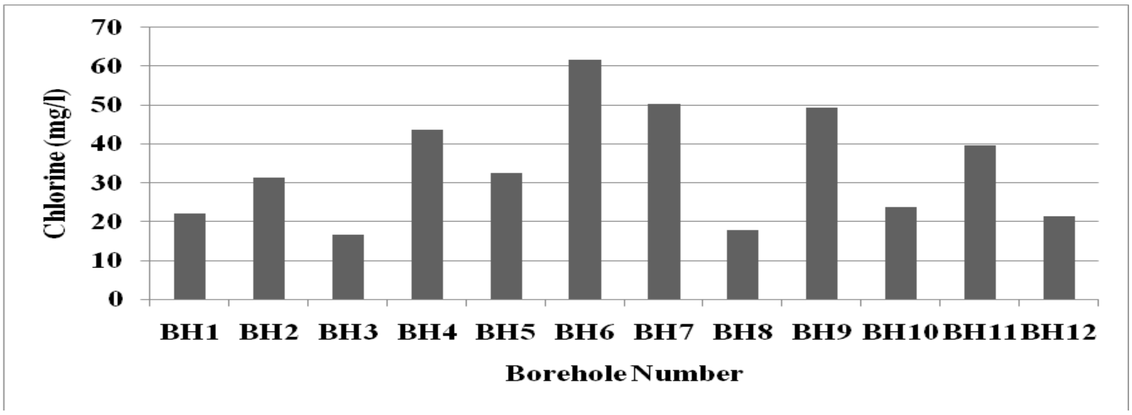

Figure 12: Chart showing variation of Chlorine across boreholes

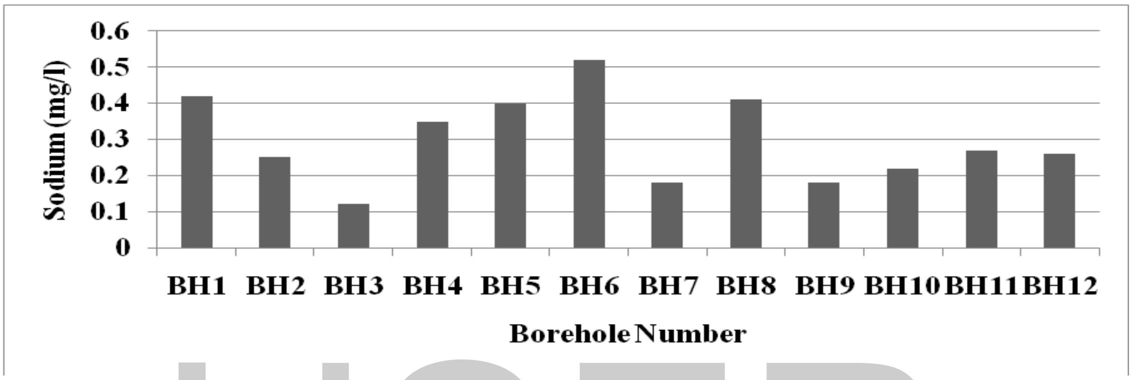

Figure 13: Chart showing variation of Sodium across boreholes

Figure 14: Chart showing variation of Potassium across boreholes

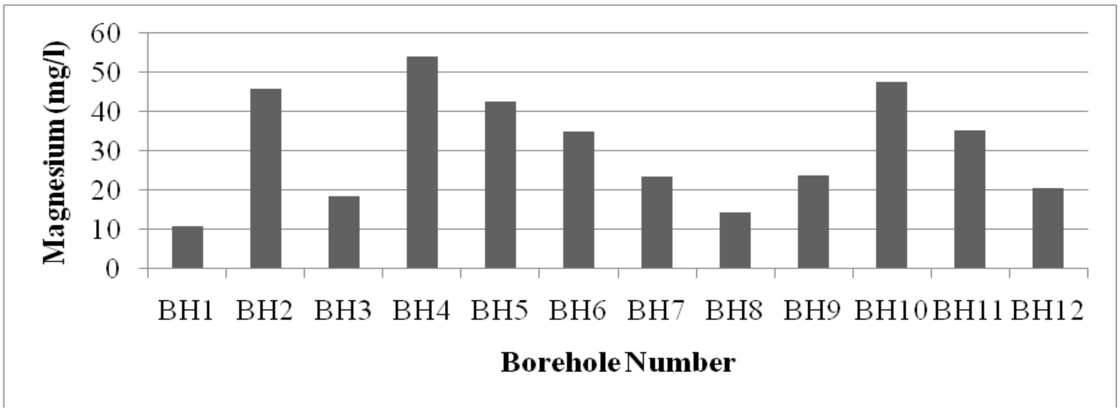

Figure 15: Chart showing variation of Magnesium across boreholes

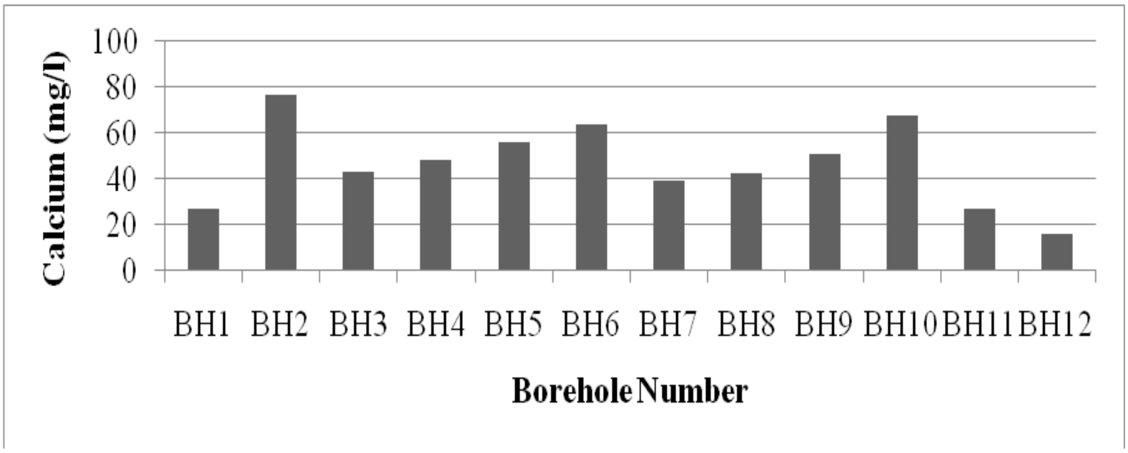

Figure 16: Chart showing variation of Calcium across boreholes

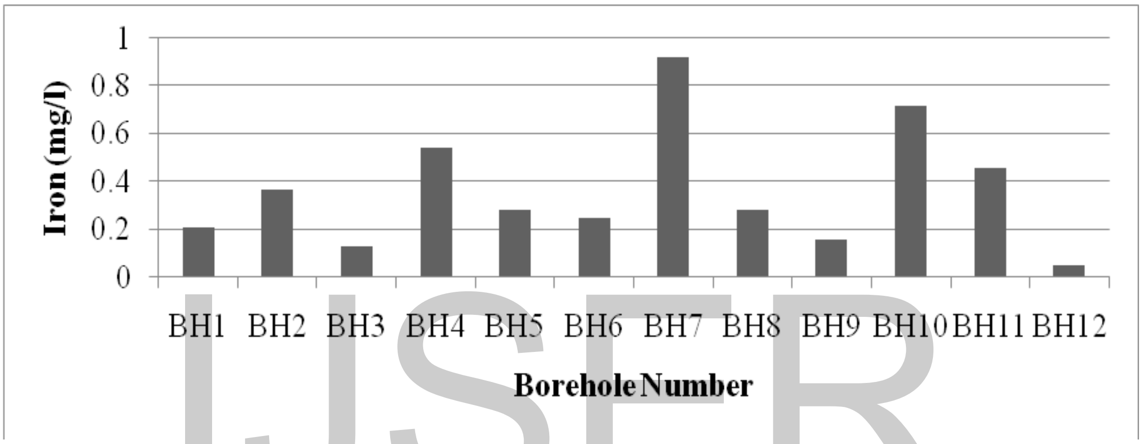

Figure 17: Chart showing variation of Iron across boreholes

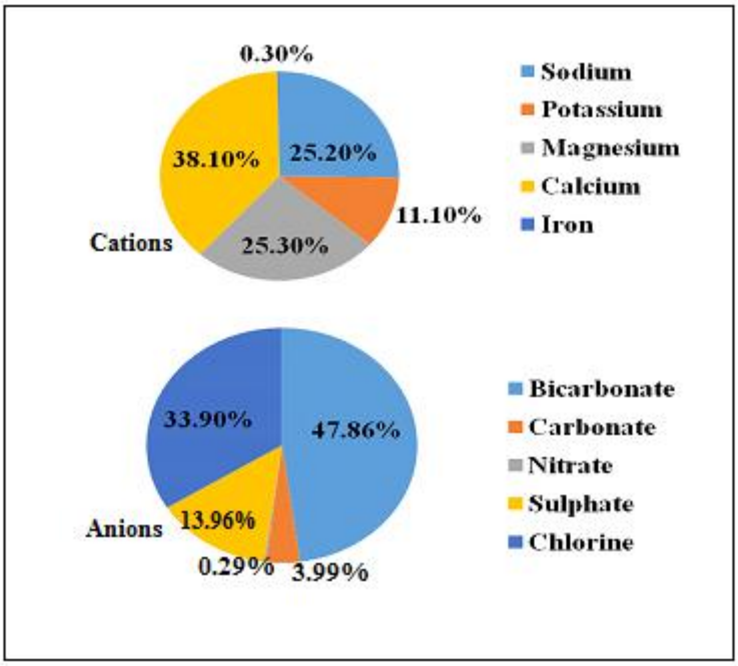

Figure 4.18: Pie Charts showing the Mean Concentration of major Cations and Anions in the Study Area

4.2. Discussion

4.2.1. Temperature

The surface atmospheric temperature in the area of study ranged between 26.2 and 28.6^{o}C. The temperature variation is due to measurements being taken at different times of the day. In an established system the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to aquatic life. Cool water is generally more potable than warm water. High temperature can promote the growth of microorganisms and can increase colour, corrosion, odour and taste challenges [23].

4.2.2 Ground-surface Elevation

Elevation varies between 6.0 and 16.0m with an average of 10.8m (Table 1; Figure 2). Elevations are greatest in the upland recharge areas where groundwater levels are deepest. Groundwater-levels at lower elevations are near valley bottoms, which are groundwater discharge areas.

4.2.3 Groundwater Level

The groundwater level from ground surface ranges between 0.4 and 2.6m with an average of 1.60m. The depth to groundwater was observed to increase with increase in elevation, being shallower towards the sea (Table 1; Figure 3).

4.3 Groundwater physicochemical analysis

4.3.1 pH

A test of the acidity of water is pH, which is a measure of the hydrogen-ion concentration. It serves as the extent of pollution by acidic or basic pollutant. The standard pH scale is from 0 to 14. A pH of 7 indicates neutral water; greater than 7, the water is basic; less than 7, it is acidic. Water that is basic can form scale; acidic water can corrode. According to U.S. Environmental Protection Agency criteria, water for domestic use should have a pH between 6.5 and 8.5.

In this study, pH value ranged from 5.80 – 7.20 (Figure 4) with an average value of 6.70. These values indicated that ground water in the area in slightly acidic, this could be attributed to the abundance of organic matters in the overlying soil and the presence of shale intercalations in the aquiferous coastal plain sands and also due to acid rain caused by prevalent gas flaring in the Niger Delta. However all the samples met the WHO standard for drinking water which is between 6.5 and 8.5. Okiongbo and Douglas [24] noted that groundwater’s in most parts of the Niger Delta region is slightly acidic. The mean pH value of 6.7mg/l indicates that the water from the region is within the WHO [23] and NSDWQ [25]) permissible values of 6.5-8.5 set aside for drinking water (Table 2). Acidity of groundwater in the Niger Delta is partly caused by gas flaring and the presence of organic matter in the soil in the area. The gas flaring from industrial activities releases carbon dioxide and other gases like sulphide which reacts with atmospheric precipitation to form carbonic and sulphuric acids.

4.3.2 Total Dissolved Solids (TDS)

TDS indicates the salinity behavior of groundwater [26]. TDS of ground water is mainly due to vegetable decay, evaporation, disposal of effluent and chemical weathering of rocks. In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. In the present investigation, the minimum value of total dissolved solids was 129.0mg/l and maximum value was 676.0mg/l (Figure 5) with the mean value is 357.25mg/l. These values are far below the stipulated value of 1000mg/l by WHO [23] for drinking water, as such, the water in Yenagao is good for consumption and irrigation purposes.

4.3.3 Electrical Conductivity (EC)

Electrical conductivity is a measure of water’s capacity to convey an electric current. This property is related to the total concentration of ionized substances in water. The more dissolved salts in water, the stronger is current flow and higher the EC. Generally, EC of water increases with salts. In this study, EC value ranged from 260µs/cm to 1357 µs/cm (Figure 6), with an average value of 697.0 µs/cm these values were below 1000µs/cm which was the WHO [23] standard for portable water.

4.3.4 Biochemical Oxygen Demand (BOD)

BOD is a measure of organic material contamination in water, specified in mg/l. BOD is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials (e.g. iron, sulphites). Typically the test for BOD is conducted over a five-day period. In this study, BOD ranges between 0.7 and 7.5mg/l with an average of 3.96mg/l (Figure 7).

4.3.5 Bicarbonate

It is also measured by titration with standardized hydrochloric acid using methyl orange as indicator. Methyl orange turns yellow below pH 4.0. At this pH, the carbonic acid decomposes to give carbon dioxide and water. Bicarbonate value, in this research, ranged from 15.3mg/l to 87.6mg/l (Figure 8) and with an average of 48.03gm/l. The source is primarily carbon dioxide in the atmosphere partly from gas and activity of biota in the soil. WHO [23] presented no limit for this parameter in water and in processing wood chemicals. Upon heating, bicarbonate is changed into steam, carbonate and carbon (iv) oxide. High bicarbonate and alkalinity concentration are undesirable in many industries.

4.3.6 Carbonate

Whenever the pH touches 8.3, the presence of carbonates is indicated. It is measured by titration with standardized hydrochloric acid using phenolphthalein as indicator. Below pH 8.3, the carbonates are converted into equivalent amount of bicarbonates. The titration can also be done pH metrically or potentiometrically. In the study area, carbonate values ranges between 1.8 and 6.3mg/l with average of 3.93mg/l (Figure 9).

4.3.7 Nitrate

The minimum value of nitrate is 0. 12mg/l and maximum value was 0.52mg/l with average of 0.298mg/l (Figure 10). This was far below the stipulated value of 50mg/l by WHO [23] standard for drinking water, hence, the water is recommended for irrigation purposes.

4.3.8 Sulphate

It is measured by nephelometric method in which the concentration of turbidity is measured against the known concentration of synthetically prepared sulphate solution. Barium chloride is used for producing turbidity due to barium sulphate and a mixture of organic substance (Glycerol or Gum acetia) and sodium chloride is used to prevent the settling of turbidity. The minimum value of sulphate was 4.70mg/l and the maximum value was 31.6mg/l (Figure 11) with a mean value of 14.05mg/l. Sulphate concentration was low in the water compared to WHO [23] stimulated limit of 400mg/l, showing that the water is safe for domestic and industrial purposes.

4.3.9 Chloride

Chloride in samples ranged from 16.5mg/l to 61.8mg/l (Figure 12) with mean value of 34.18mg/l. All samples except BH1, BH2, BH3, BH5, BH8, BH10 and BH12 showed values less than 40mg/l stipulated by Oki and Ombu [27] which indicate salt-water intrusion. WHO [23] stipulated 250mg/l as the limit of chloride in drinking water.

4.3.10 Sodium

It is measured with the help of flame photometer. The instrument is standardized with the known concentration of sodium ion (1 to 100 mg/l). The samples having higher concentration are suitably diluted with distilled water and the dilution factor is applied to the observed values. The value of Sodium ranged from 14.4mg/l to 55.2mg/l (Figure 13) with an average value of 30.86mg/l. There is also no limit by WHO [23] for this parameter. But excess sodium in water may be harmful.

4.3.11 Potassium

It is also measured with the help of flame photometer. The instrument is standardized with known concentration of potassium solution, in the range of 1 mg to 5 mg/litre. The sample having higher concentration is suitably diluted with distilled water and the dilution factor is applied to the observed values. The range of value for Potassium in the water sample analysis is 5.1mg/l to 26.4mg/l with average of 13.63mg/l (Figure 14). There is no guideline for potassium in drinking water by WHO ([23].

4.3.12 Magnesium

It is also measured by complexometric titration with standard solution of EDTA using Eriochrome black T as indicator under the buffer conditions of pH 10.0. The buffer solution is made from Ammonium Chloride and Ammonium Hydroxide. The solution resists the pH variations during titration. The Magnesium value ranged from 10.90mg/l to 54.00mg/l (Figure 15) with an average value of 30.98mg/l, all samples were above the stipulated value of 50 mg/l by WHO [23] for water drinking.

4.3.13 Calcium

It is measured by complexometric titration with standard solution of ETDA using Patton's and Reeder's indicator under the pH conditions of more than 12.0. These conditions are achieved by adding a fixed volume of 4N Sodium Hydroxide. The volume of titre (EDTA solution) against the known volume of sample gives the concentration of calcium in the sample. The value of calcium ranged from 16.20mg/l to 76.50mg/l (Figure 16) with a mean value of 46.56mg/l. The presence of calcium in water from the study area is as a result of the dissolution of feldspars and micas in the Benin formation and the adjourning basement complex areas. Values were below the WHO [23] limit of 75mg/l for safe drinking water. Thus the water is harmless and safe with regards to this parameter.

4.3.14 Iron

The content of iron in the water samples ranged from 0.13mg/l to 0.92mg/l (Figure 17) with an average value 0.36mg/l. Iron with a mean value of 0.36mg/l for wet season (Table 1). The WHO [23] standard and NSDWQ [25] for this parameter is 0.3mg/l. Thus the water from the area is high in iron content, with some areas exceeding the WHO [23] and NSDWQ [25] limits. Exposure of these water samples to air would lead to the oxidation of Fe2+ ion to Fe3+ ion and precipitate a rust coloured ferric hydroxide which can stain utensils. The Benin Formation which is the water bearing aquifer, from where the groundwater seeps into the wells are ferruginous, and contains iron minerals such as, marcasite, hematite, goethite and limonite. The mobility and subsequent downward infiltration of these minerals through the porous and permeable formation account for the presence of iron in the water from the study area [28].

4.3.15 Cations and Anions

A pie chart (Figure 18) showed that the maximum cation found in the water samples was calcium (38.10%) and iron is the lowest (0.3%) in the study area. Also, considering the concentration of anions, bicarbonate was highest (47.86%), and the lowest was nitrate (0.29%). The concentrations of these major cations and anions falls within the allowable limits permitted by WHO [23] for portable water.

5 CONCLUSION

From the findings, the following conclusions are established. The surface atmospheric temperature in the area of study ranged between 26.2 and 28.6^{o}C. The groundwater level from the ground surface from the locations ranges from a minimum of 8m to 18m. The depth to groundwater was observed to increase with increase in elevation, being shallower southwards towards the sea. Elevation varies between 6.0 and 16.0m with an average of 10.8m. Elevations are greatest in the upland recharge areas where groundwater levels are deepest. Groundwater-levels at lower elevations are near valley bottoms, which are groundwater discharge areas. pH value ranged between and 5.80 and 7.20 with an average value of 6.70. These values are indicative of the groundwater in the area is slightly acidic; this could be attributed to the abundance of organic matters in the overlying soil and the presence of shale intercalations in the aquiferous coastal plain sands. However all the samples met the WHO [23] standard for drinking water which is between 6.5 and 8.5.

From the results of all the measured and analysed parameters of interest in this work, it is evident that the ranges of the concentrations of the analysed elements and compounds fall within the WHO [23] established standard permissible limits for portable water. The obtained groundwater levels, elevations and physicochemical parameters can be used for groundwater management. Moreso, water analysis data should be collected continuously in the study area, the data could aid the building of hydro-geochemical models, which could in turn be used to make informed predictions about changes in groundwater quality.

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