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Hydrochemical Characteristics of Groundwater in Elele, Rivers State, South-South Nigeria

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Abstract

Ten water samples were taken from boreholes in parts of Elele, Rivers State, Port-Harcourt to assess the quality status. Samples were properly labeled and were taken to the laboratory within twenty Four hours for inventory investigations. The overall, essence is to appraise the water suitability for aesthetic and domestic use. The analyzed values were compared with the regulating standards such as (WHO, 2006,), (FME 2002). In comparison with the standards the results were within the acceptable limits. The results obtained shows that the water samples quality examined compared favourably with WHO (2006) standard for drinking water. Although the values for p^H (6.4 and 5.10 in borehole 1 and 6 respectively), and Fe^{2+} (0.46, 0.45, 0.32 and 0.52 in boreholes 4, 8, 9 and 10 respectively) slightly exceeded the WHO (2006) permissible limits for safe drinking water. The water at these locations should be treated otherwise it could cause objectionable tastes and could stain plumbing fixtures and laundered clothes. Piper trilinear diagram further characterizes the groundwater in the study area to be dominated by alkali earth (Ca^{2+} + Mg^{2+}) for the cations and strong acids (SO_4^{2-} + Cl^-) for the anions. Trilinear plots of the results show a dominant of one hydrochemical facies type in the area: Mg-SO_4^{2-} facies.

Keywords: Hydrochemical, Groundwater, Water Suitability, Elele.

Introduction.

Water is one of the most essential needs of human beings and it is the most abundant natural resources on the surface of the earth. (Oyinloye and Jegede, 2004). Groundwater is essential to man and it is one of the best water available. There is a global recognition that the quantity of groundwater is as important as its quality. The quantity of groundwater depends upon the geological environment, natural movement, recovery and utilization. Current emphasis is not only on how abundant water is but also on whether its quality status is good enough to sustain its various uses (Udom et al. 1999). The quality of ground water determines its usability for domestic, industrial and agricultural purposes. The quality of groundwater at any point below the surface reflects the combined effects of many processes along the groundwater flow part. Chemical reactions such as weathering, dissolution, precipitation, iron exchange and various biological processes commonly take place below the surface. Hydrogeochemical study is a useful tool to identify these processes that are responsible for groundwater chemistry.

Research in science and technology has created the awareness of the importance and benefits of good quality water to human health as well as to agricultural and industrial purposes.

The people of Elele use ground water mainly for drinking and other domestic purposes. Hence it has become necessary to study the quality of the water in the area to access its suitability for various uses

Location of The Study Area

The study area is located in Ikwerre Local Government Area, Rivers State within the Niger Delta Basin between latitude $5^0 6'6''$N and Longitude $6^0 48'51''$E. It is bounded to the north by Egbeda town, to the south by Alimini-Elele town, to the east by Isiokpo town, and to the west by Omudioga town. The study area which lies within the Niger Delta has a climatic condition modeled by such elements as rainfall (precipitation), relative humidity, temperature, wind and sunshine.

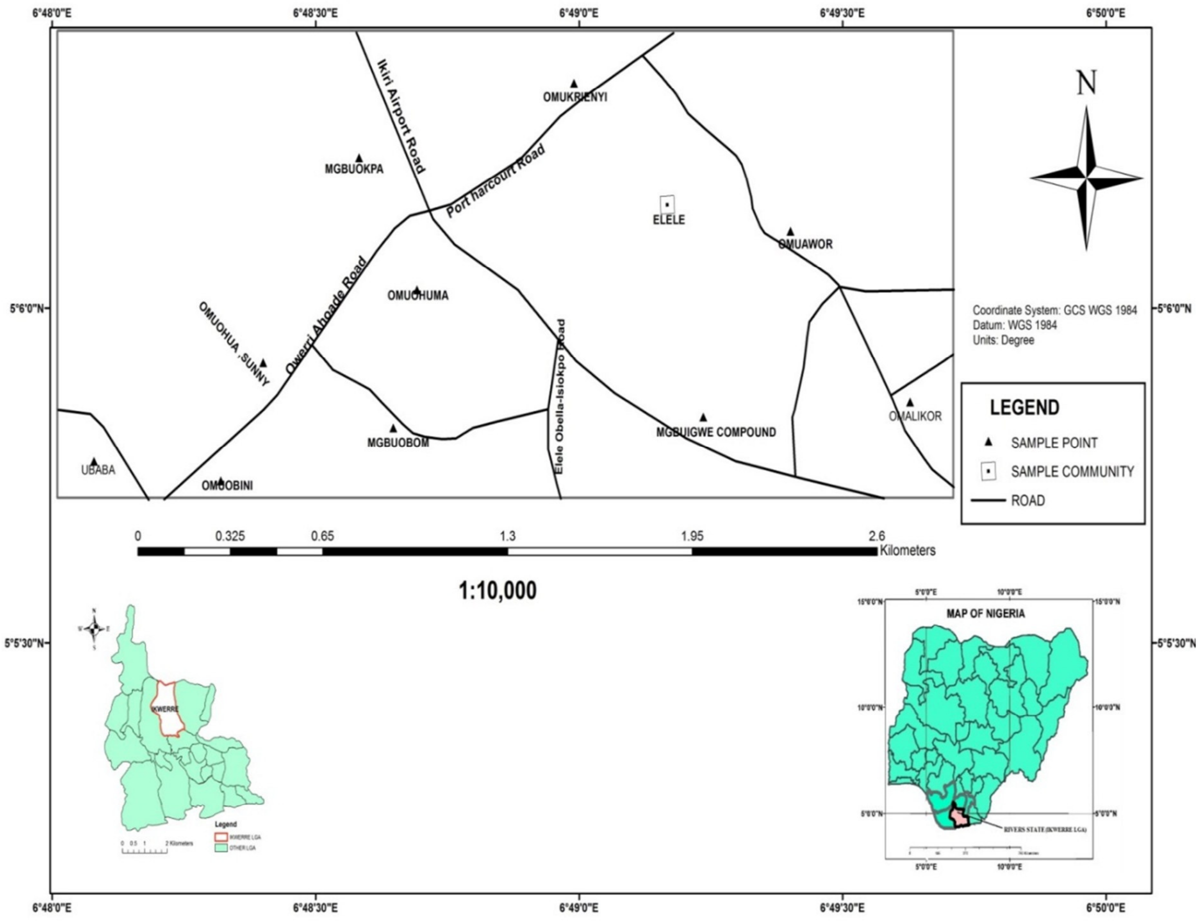


FIG.1: MAP SHOWING LOCATION OF THE STUDY AREA

Geology of the Study Area

The study area is within the Niger Delta. The geology of the Niger Delta has been extensively described by Allen (1965), Reyment (1965), Short and Stauble (1967), Aseez (1976), Wright et al (1985), Kogbe (1989), and others. The Niger Delta Basin was formed by a failed rift junction during separation of the South American plate and the African plate, as well as the opening of the South Atlantic. Rifting in this basin started in the Late Jurassic and ended in the Mid Cretaceous. As rifting continued several faults formed, many of them thrust faults. The delta covers a land area in excess of 105,000 km^2 (Avbovbo, 1978). The Niger Delta is a prograding depositional complex with the formation of southern Nigeria. It extends from the Calabar flank and the Abakaliki Trough in Eastern Nigeria the Benin flank in the west and it opens to the Atlantic Ocean in the south. Its apex is situated southeast of the confluent of the Niger and Benue Rivers. It lies mainly in the Gulf of Guinea to the Southwest of the Benue Trough and constitutes the most important Cenozoic construction in the South Atlantic

Method of Study

Groundwater samples were collected in clean 150cl (1.5 liter) plastic bottles. Borehole samples were gotten from the closest taps to the wellhead. The boreholes are all used for drinking water supply. The taps were run for some time until the temperature of the water remained constant before samples were taken. This was to ensure collection of representative samples from the aquifer. The bottles were first washed several times with the sample water before collection in order to avoid any contamination. After each sampling, the bottle was capped immediately to minimize oxygen contamination and the escape of dissolved gases. The samples were then carried in ice-packed coolers to the laboratory for analysis within 24 hours.

Temperature was determined in the field due to its unstable nature. All other parameters were analyzed in a standardized laboratory using international regulatory methods (WHO, 2006).

The global positioning system (GPS) Garmin 76csx which is satellite based equipment for position determination was used to record the longitude and latitude of each borehole locations evenly distributed within the study area.

Table 3.1: Sample locations of all the boreholes in Elele, Rivers State.

Borehole Numbers	**Sample Locations**	**Latitudes**	**Longitudes**
BH1	Omalikor	5.09736^{0}N	6.82523^{0}E
BH2	Mgbuigwe (Omopo)	5.09701^{0}N	6.81961^{0}E
BH3	Omuawor	5.10139^{0}N	6.82259^{0}E
BH4	Mgbuobom	5.09680^{0}N	6.81128^{0}E
BH5	Omuohuma	5.09997^{0}N	6.81177^{0}E
BH6	Mgbuokpa Monkey st.	5.10333^{0}N	6.80992^{0}E
BH7	Omuohua, Sunny Mill street	5.09825^{0}N	6.80761^{0}E
BH8	Omuobini	5.09571^{0}N	6.80678^{0}E
BH9	Ubaba	5.09600^{0}N	6.80336^{0}E
BH10	Omukrienyi	5.10518^{0}N	6.81635^{0}E

Temperature Determination

Mercury filled Celsius thermometer (10 -110^{0}C) graduated in 0.2^{0}C divisions was used to measure the water temperature. The thermometer was emerged in the water for about 5minutes and readings recorded. Two buffer solutions of pH 4 and 9.0 and pH meter. The two buffer solutions were used to calibrate the pH meter. After the calibration, the pH of the samples were determined by dipping the electrode in the water sample and the pH meter reading recorded, the electrode was rinsed with distilled water after determination. Electrical conductivity meter (EC meter) and a beaker. Water sample was put in a beaker and the electrode connected to the meter bridge was immersed completely in the water. The readings were taken in micro Ohm/cm.Evaporating dish, desiccator and weigh. The gravimetric method was used, where 50ml of sample was measured into an evaporating dish which was initially weighed empty. This sample then heated to total dryness. The residue was allowed to cool in a desiccators and then reweighed**.** The bicarbonate 100ml of the sample was measured into 250ml Erlenmeyer flask and titrated against standard 0.01m HCl using Methyl red as the indicator. At the end point, the color changed from yellow to orange. **CHLORIDE (Cl^-) –** Micro burette, beaker, conical flask. 25ml of the sample was measured into a 250ml conical flask. And a few drops of potassium dichromate (K_2CrO_4) were added as an indicator and then the solution was titrated against standard 0.1m silver nitrate ($AgNO_3$) solution until the appearance of a brick red color. **SULPHATE (SO_4^{2-}) – DETERMINATION** Magnetic stirrer, Spectrophotometer, stopwatch, measuring spoon, volumetric flask, weighing balance. 10ml of water sample was measured into a 25ml standard flask, distilled water was added to the flask containing the water sample increasing the volume to 20ml. 1ml of Gelatin-Barium Chloride ($BaCl_2$) reagent was then added and the volume increased up to the 25ml mark. The content was thoroughly mixed and allowed to stand for 30 minutes. Thereafter, the absorbance was determined spectrophotomerically at 420nm within 30 minutes of standard calibration curve. The observed color was then measured at specific wavelength and sulphate concentration determined. **NITRATE (NO_3^-)** spectrophotometer **.**The wagtech water kit was used to determine the amount of NO_3^-. The appropriate tablet was grounded into powder and dissolved in 10ml sample. It was left to stand for ten minutes (10min) and read at the appropriate wavelength on the wagtech spectrophotometer. The reading was read from a table supplied by the company. **CALCIUM (Ca^{2+}) / MAGNESSIUM (Mg^{2+})** Atomic Absorption Spectrophotometer, Volumetric Flask, Pipette, Weighing Balance. The samples were atomized and absorbance readings were recorded for the various samples. At least four standard solutions were prepared. All dilutions were made with HCL (1=99). The standard was prepared each time the test was to be performed. The wavelength of the instrument was set to 422.7nm for calcium or 285.2nm for magnesium by atomizing standards. The standards were atomized to record the instrument readings in absorbance units. Water was atomized between each standard. **SODIUM (Na^+)** Atomic Absorption Spectrophometer, Volumetric Flask, Pipette and Weighing Balance. Each sample was aspirated and its Absorbance determined at 766.5nm or concentration. 100ml each of a blank and at least four standards solutions were prepared by diluting the standard sodium solution. The standards were prepared each time the test was to be performed. **POTASSIUM (K^+)** .Atomic Absorption Spectrophotometer, Volumetric Flask, Pipette and Weighing Balance. Potassium was determined by atomic absorption spectrometry. Dissolved potassium was determined by aspirating the filtered sample directly without pre-treatment. **IRON (Fe^{2+}).**Atomic Absorption Spectrophotometer, weighing balance, Volumetric Flask, pipette. 50ml of the sample was measured into a 125ml Erlenmeyer flask followed by 2ml concentration of HCl and 1ml of $NH_2OH.HCl$. The mixture was boiled for about 5 minutes, cooled at room temperature and transferred into a 100ml volumetric flask. 10ml $NH_4C_2O_3H_2$ buffer solution and 2ml phenolphthalein solution were added and diluted to mark with water. The solution was mixed thoroughly and allowed to stand for maximum color development. The absorbance was measured at 510nm. **BIOLOGICAL OXYGEN DEMAND (BOD) –** Volumetric flask, stock bottles, beaker and pipette. BOD test are generally carried out by measuring the amount of dissolved oxygen do present in the sample before and after the incubation in the dark for 5days at 20^{o}C. The procedures include. Phosphate Buffer Solution: Consist of 8.5g of Potassium Dihydrogen Phosphate

KH_2HpO_4, 33.4g disodium hydrogen phosphate Va_2HPO_4. $7H_2O$ and 1.7g ammonium chloride NH_4Cl in a liter of solution. This is preserved in stock bottles. Magnesium sulphate solution ($MgSo_4^{2-}$): 22.5g magnesium sulphate ($MgSo_4$) $7H_2O$ was dissolved in a flask and made up to the mark with distilled water. Calcium Chloride Solution: 27.5g of calcium chloride ($CaCl_2$) was dissolved in 1liter of solution.

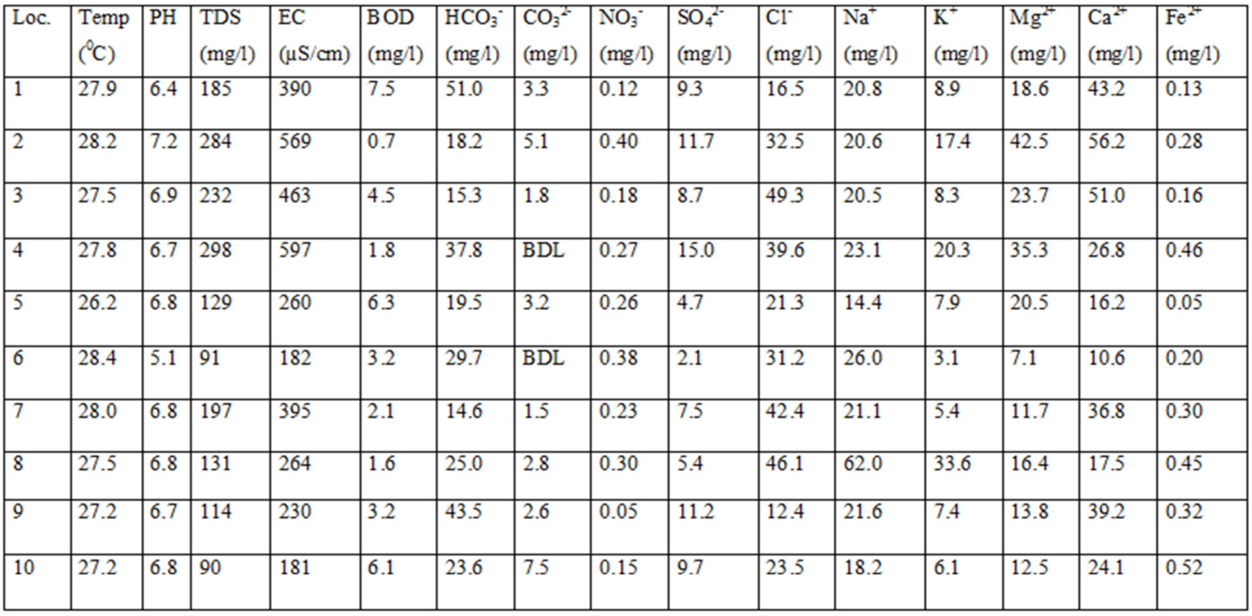
Result And Discussion

Table 3.2: Ranges in values of parameters in the study area compared to WHO (2006) and NSDWQ (2007) standard for drinking water.

Parameters	**Who Standard (2006)**	**Nsdwq (2007)**	**Range**	**Mean**	**Standard Deviation**
Temp	NS	NS	26.2-28.4	27.59	0.63
pH	6.5-6.8	6.5-6.8	5.1-7.2	6.62	0.57
TDS	1000	500	90-298	175.1	76.66
EC	1400	1000	94-597	353.1	153.5
BOD	6-9	NS	0.7-7.5	3.7	2.30
HCO_3^-	NS	NS	14.6-51.0	27.82	12.50
CO_3^{2-}	NS	NS	1.5-7.5	2.78	2.27
NO_3^-	40-70	50	0.05-0.40	0.23	0.11
SO_4^-	400	100	2.1-15.0	8.53	3.77
Cl^-	250	250	12.4-49.3	31.48	12.80
Na^+	200	200	14.4-62.0	24.83	13.40
K^+	50	NS	3.1-33.6	11.84	9.33
Mg^{2+}	150	0.20	7.1-42.5	20.21	11.05
Ca^{2+}	200	NS	10.6-56.2	32.16	15.47
Fe^{2+}	0.3	0.3	0.05-0.52	0.29	0.16

*NS = NOT STATED.

Table 4.2: Physical and chemical parameters of groundwater samples of the study area.



Loc.	Temp (^0C)	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)
1	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
2	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
3	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
4	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
5	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
6	28.4	5.1	91	182	3.2	29.7	BDL	0.38	2.1	31.2	26.0	3.1	7.1	10.6	0.20
7	28.0	6.8	197	395	2.1	14.6	1.5	0.23	7.5	42.4	21.1	5.4	11.7	36.8	0.30
8	27.5	6.8	131	264	1.6	25.0	2.8	0.30	5.4	46.1	62.0	33.6	16.4	17.5	0.45
9	27.2	6.7	114	230	3.2	43.5	2.6	0.05	11.2	12.4	21.6	7.4	13.8	39.2	0.32
10	27.2	6.8	90	181	6.1	23.6	7.5	0.15	9.7	23.5	18.2	6.1	12.5	24.1	0.52

BDL = Below Detection Limit.

Table 3.3: Correlation matrix between the parameters

	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)
TDS (mg/l)	0.2149												
EC (µS/cm)	0.1648	0.9984											
BOD (mg/l)	0.0173	0.1785	0.1598										
HCO_3^- (mg/l)	0.0989	0.0096	0.005	0.0828									
CO_3^{2-} (mg/l)	0.0034	0.5907	0.5964	0.8581	0.0005								
NO_3^- (mg/l)	0.0492	0.069	0.0612	0.3115	0.2144	0.0675							
SO_4^{2-} (mg/l)	0.3241	0.4412	0.4447	0.0409	0.0925	0.0408	0.0952						
Cl^- (mg/l)	0.0221	0.1958	0.1791	0.3004	0.3622	0.0117	0.2184	0.0045					
Na^+ (mg/l)	0.0009	0.0276	0.0284	0.1773	1E-05	0.0726	0.0657	0.0755	0.1988				
K^+ (mg/l)	0.1341	0.0956	0.0942	0.2655	3E-06	0.0013	0.1121	0.0368	0.1965	0.6473			
Mg^{2+} (mg/l)	0.3063	0.7457	0.7405	0.1387	0.0088	0.3909	0.1262	0.4285	0.0442	0.0194	0.1878		
Ca^{2+} (mg/l)	0.3022	0.3932	0.4026	0.012	0.0008	0.265	0.0551	0.3343	0.0023	0.1065	0.0052	0.2802	
Fe^{2+} (mg/l)	0.0483	0.0001	1E-06	0.1895	0.0007	0.3373	0.0007	0.1842	0.0491	0.1668	0.2129	0.0015	0.0268

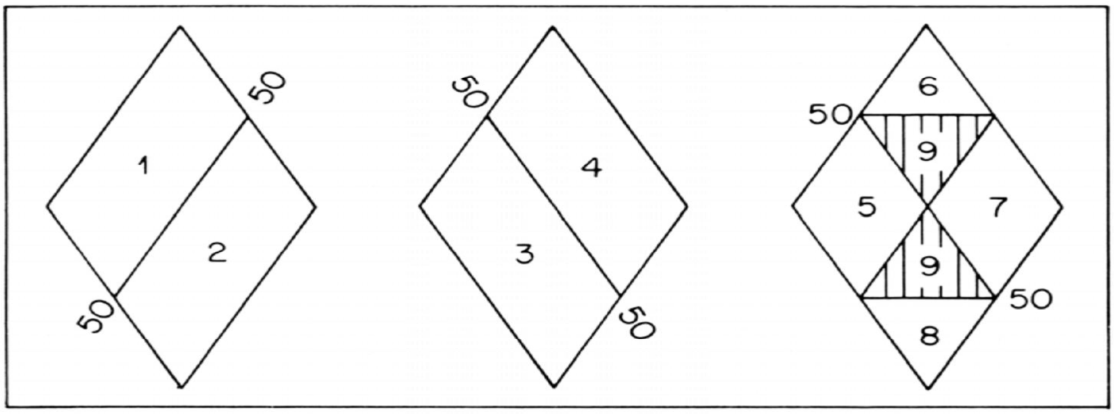


Figure 4.2: Subdivisions of the diamond-shaped field of the Piper diagram

Diagram segments (figure 4.1).

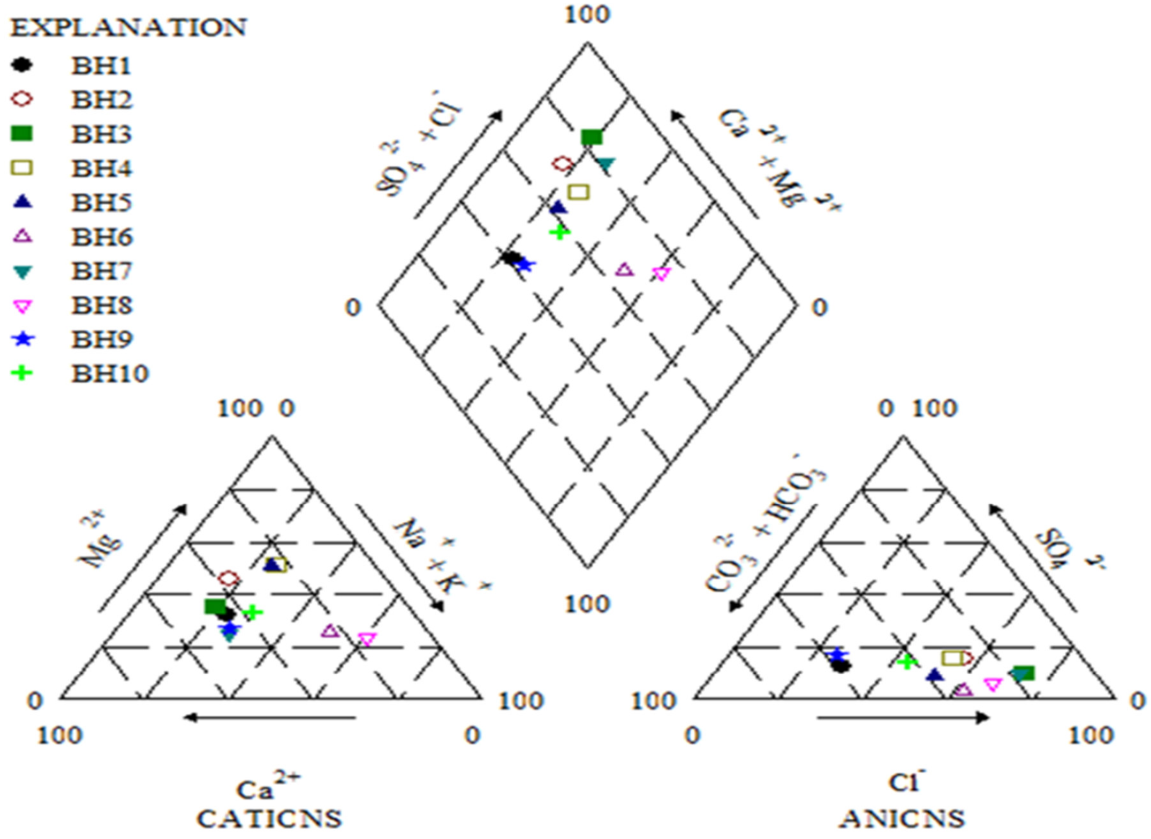


Figure 4.1: Piper Trilinear Diagram

TABLE 3.4: Characterization Of Groundwater Of Study Area On The Basis Of Piper Tri-Linear Diagram.

Subdivision	**Characteristics of corresponding subdivision of diamond shaped field**	**Samples**
1	Alkali earths ($Ca^{2+} + Mg^{2+}$) exceed alkalis ($Na^+ + K^+$)	All (except 6 and 8)
2	Alkalis ($Na^+ + K^+$) exceeds alkali earths ($Ca^{2+} + Mg^{2+}$)	2 (6 and 8)
3	Weak acids ($CO_3^{2-} + HCO_3^-$) exceed strong acids ($SO_4^{2-} + Cl^-$)	2 (1 and 9)
4	Strong acids exceed weak acids	All (except 1 and 9)
5	Carbonate hardness (secondary alkalinity) exceeds 50% (chemical properties are dominated by alkali earths and weak acids)	2 (1 and 9)
6	Non-carbonate hardness (secondary salinity) exceeds 50% (chemical properties are dominated by alkali earth and strong acids)	3 (2, 3 and 7)
7	Non-carbonate alkali (primary salinity) exceeds 50% (chemical properties are dominated by alkalis and strong acids)	2(6 and 8)
8	Carbonate alkali (primary alkalinity) exceeds 50% (chemical properties are dominated by alkalis and weak acids)	Nil
9	No cat ion – anion pair exceeds 50%	3(4, 5 and10)

The quality of any water resources is its suitability for the intended use. This thus, is a function of the physical, chemical and biological (bacteriological) characteristics of the water which in turn depends on the geology of the area and impacts of human activities (H.O. Nwankwoala, 2011). The results of the laboratory measurements of pH, conductivity, BOD and total dissolved solids (TDS), as well as major ions (Ca^{2+}, Na^+, Mg^{2+}, K^+, Fe^{2+}, HCO_3^-, CO_3^{2-}, NO_3^-, Cl^-, and SO_4^{2-}) are presented in Table 3.2. The average temperature of the water samples was calculated to be about 27.59 with a minimum value of 26.2^{OC} and a maximum value of 28.4^{OC}. A standard deviation of 0.63 was calculated. The temperature values were found to remain approximately constant throughout the duration of the fieldwork; proving the advantage of groundwater over surface water. The value of pH ranges between 5.1 mg/l to 7.2mg/l with a mean value 6.62mg/l of and a standard deviation of

0.57mg/l, indicating slightly acidic to slightly alkaline groundwater in the area. WHO puts the acceptable range of p^H in drinking water at 6.5 -8.5. With respect to this standard, groundwater samples from location 1 and 6 need treatments to raise the pH to at least 6.5. This can effectively be achieved with the base- exchange method using dolomite. The slight acidity in groundwater in the area may be due to the oxidation of dissolved ferrous iron or the presence of organic matter in the soil, or it could even be associated with gas flaring in the area. This phenomenon releases CO into the atmosphere and during precipitation; this gas can enter the groundwater system as the rainwater percolates the water underground to reduce p^H. Acidic waters promote the growth of iron bacteria which cause incrustation of pipes. Results of the study reveal that the Electrical Conductivity (EC) values ranges between 94- 497uS/cm with a mean value of 353.1uS/cm and standard deviation of 153.5. These values are lower than the stipulated value of 1400uS/cm by WHO (2006) in drinking water. Electrical conductivity up to 2000uS/cm is permissible for irrigation hence the water would not be injurious to crops in the area. According to Langenegger (1990), the importance of EC is its measure of salinity, which greatly affect the taste and thus has a significant impact on the users' acceptance of the water as portable. The Total Dissolved Solid (TDS) value ranges from 90 – 298mg/l, with an average of 175.1 mg/l and a standard deviation of 76.66mg/l (table 3.1). This falls below the standards of 1000mg/l by WHO (2006) and 500mg/l by NSDWQ (2007) for drinking water, hence the water is not harmful to its potential users. It is also very supportive for irrigation purpose. In water sample, the total dissolved solids include all solid materials in solution whether ionized or not. It does not include suspended sediments, colloids and dissolved gases. The Biochemical Oxygen Demand (BOD) is reported to be a fair measure of cleanliness of any water on the basis that values less than 1-2mg/l are considered clean, 2-3mg/l fairly clean, 5mg/l doubtful and 10mg/l definitely bad and polluted. This shows that the quality of groundwater in the study area is a little bit worrisome in terms of BOD concentration. Although the BOD value which ranges between 0.7-7.5mg/l raised some concern, it is still within the WHO (2006) permissible limit of 6-9mg/l; hence the groundwater in the study area is suitable for drinking and for other domestic purposes. The mean value for all boreholes is 3.7mg/l with standard deviation of 2.30mg/l (table 3.1). The occurrence of BOD can be connected to the presence of decomposable organic matter. Bicarbonate (HCO_3) in the water ranges from 14.6-51.0mg/l, with a mean of 27.82mg/l and a standard deviation of 12.50 (table 3.1). But no limit is stated for this parameter in drinking water by WHO (2006) and NSDWQ (2007). However, its source is attributed to carbon dioxide dissolved in naturally circulating water. This also contributed to the lowering of the pH of groundwater concentration, increase in water with low calcium and magnesium contents. Some high values were observed which could be due to high vegetation and decayed plants around the area or some localized effects. The carbonate (CO_3^{2-}) values range from 1.5mg/l-7.5mg/l. Ccarbonate has a mean value of 2.78 with a standard deviation of 2.27 (table 3.1). No limit is stated for this parameter in drinking water by WHO (2006). Most carbonate ions in ground water are derived from the carbon dioxide in the atmosphere, carbon dioxide in the soil, carbon dioxide produced by the biota of the soil or by the activity of sulphate reducers and other bacteria in deeper formations and solutions of carbonate rocks. Carbonates occur mainly as carbonates of sodium, magnesium, and potassium. Carbonates of sodium and potassium are water soluble while those of calcium and magnesium are insoluble.

Nitrate (NO_3^-) recorded a mean value of 0.23mg/l. Min 0.05mg/l and Max is 0.40mg/l. The standard deviation is 0.11 these values are very low compared to the acceptable limits for drinking water; 40 - 70mg/l by WHO (2006) and 50mg/l by NSDWQ (2007) hence the groundwater in the area is potable for drinking. Normally, nitrate pollution is associated with septic systems and agricultural activity. Nitrate is an essential ingredient of plant nutrition. It occurs in soils, and can be fixed by leguminous plants. Nitrates are regarded as an indicator of pollution in public water supply. The sulphate (SO_4^{2-}) values range from 2.1-15.0. Sulphate has a mean value of 8.53with a standard deviation of 3.77. Sulphate concentration is low in the water when compared with the WHO (2006) standard of 400mg/l and that of NSDWQ (2007) which is 100mg/l. this shows that the water is not injurious to health. These very low concentrations of sulphate suggest absence of any abuse of the water by septic tanks in the area. The Sulphate probably owes its source in the area to industrial waste from adjoining areas. Chloride (Cl^-) content in the water averages 31.48mg/l, with a minimum value of 12.4mg/l and a maximum value of 49.3mg/l which is less than the benchmark value of 250mg/l stipulated by WHO (2006) for potable water. Almost all the samples are less than the 40mg/l stipulated by Tremblay et al (1973) to indicate salt-water intrusion. Salt water contamination is a common groundwater pollution problem in most coastal areas of the world, particularly where there is over abstraction of groundwater from the hinterland, causing the saltwater freshwater interface to move inland. This problem had earlier been identified in other parts of Rivers State by Udom et al.1999, Ngerebara & Nwankwoala 2008, Nwankwoala and Udom, 2011. Sodium (Na^+) content in the water averages 24.83mg/l, with a minimum value of 14.4mg/l and a maximum value of 62.0 mg/l. it has a standard deviation of 13.40mg/l. The concentration level of Na is lower than the permissible level of 200mg/l by WHO (2006) in all the locations (Table 3.2). Thus, the groundwater in the area is safe in view of this parameter. Sodium occurs widely in water and in many igneous rocks. It is an essential component of most groundwater, but more abundant in saline water. Sodium in excess of 50mg/l in the presence of suspended matter causes foaming and facilitates scale formation and corrosion boilers. Due to its deleterious effect on soils and plants, sodium is considered a major factor governing the choice of water for irrigation. Potassium (K^+) value ranges from 3.1-33.6mg/l, with an average of 11.84mg/l and a standard deviation of 9.33 mg/l (table 3.1). The concentration levels of potassium are less than those of sodium in the water. The values for this parameter are considerably below the limit for the guidelines for safe drinking by WHO (2006). Potassium is usually found only in small quantity in groundwater, this is because when potassium is leached from rocks it easily recombines with other minerals. The presence of potassium in groundwater is usually accounted for by weathering of micas and feldspars. Magnesium value ranges from 7.1-42.5 with a mean of 20.21and a standard deviation of 11.05. The limit for magnesium in drinking water is 150mg/l as assigned by WHO (2006). The average or even the maximum value is too low to make the water unsuitable for domestic or agricultural uses. Common source of magnesium ion in natural water are dolomite, olivine and hornblende etc. It is also associated with calcium carbonate ($CaCO_3$). A high concentration has a laxative effect. Calcium (Ca^{2+}) recorded a mean value of 32.16mg/l. Min 10.6mg/l and Max is 56.2mg/l. The standard deviation is 15.47 these values are very low compared to the acceptable limits for drinking water which is 200mg/l by WHO (2006). Based on this result, the water is suitable for drinking and most industrial processes. These low values are correlatable to low hardness values in the area because Ca and Mg are the two constituents which cause hardness in water. Calcium in water usually owes its origin from silicates and feldspars which characterize the Coastal Plain Sands where the borehole tap water from. Total Fe ranges in concentration from 0.05-0.52mg/l, it has a mean of 0.29mg/l and a standard deviation 0f 0.16mg/l. WHO (2006) and NSDWQ (2007) standards for iron in water meant for drinking is 0.3mg/l. comparison of the results with this standard shows that there is iron contamination at the boreholes in location 4, 8, 9 and 10. The water at these locations should be treated otherwise it could cause objectionable tastes and could stain plumbing fixtures and laundered clothes. The common form of iron in groundwater is the soluble ferrous iron (Fe^{2+}) of which the concentration are normally in the range of 1-10mg/l. The state of occurrence of iron in water depends on the p^H. Aeration and filtration method could be a suitable treatment method. Here the water is exposed to the atmosphere so that Fe could oxidize to Fe and precipitate ferric-hydroxide which is then filtered out. The primary source of the iron is geologic. Iron is abundant in iron-bearing minerals of igneous, metamorphic and sedimentary rocks. It occurs in minerals like pyroxene, amphibolites etc. Correlation coefficient is a commonly used measure to assess the relationship between two variables (Edet et al, 2011). It is a simple measure to exhibit how well one variable predicts the other. It gives insight into the relationship or interdependence of the various physiochemical parameters on one another. The correlation determination (R^2) among fourteen water quality parameters namely pH, EC, TDS, Ca^{2+},Mg^{2+}, Na^+, K^+, Fe^{2+}, BOD, HCO_3^{2-},CO_3^-, NO_3^-, SO_4^{2-}, and Cl^- were calculated using regression analysis. The correlation matrix for the different variables is shown in Table 3.3. The data illustrate that EC and TDS show statistically high positive correlation with CO_3^{2-} and Mg^{2+}. EC and TDS also show good (moderate) relationship with BOD, SO_4^{2-}, Cl^-, and Ca^{2+}. These correlations indicate that the ions are derived from the same source. High positive relationship is also observed by the correlation between BOD vs. CO_3^{2-} and Na^{2+} and K^+. p^H shows a poor relationship with all the anions (less than 0.1) with the exception of SO_4^{2-}, it also shows poor correlation with BOD, Na^+, and Fe^{2+}. HCO_3^- shows poor relationships with all the parameters it was correlation with exception of Cl^- and NO_3^{2-}, same thing is applicable to CO_3^{2-}. CO_3^{2-} shows poor relationships with all the parameters it was correlated with exception of Mg^{2+}, Ca^{2+} and Fe^{2+}. The correlation between NO_3^{2-} - SO_4^{2-}, NO_3^{2-} - Na^+, NO_3^{2-} - Ca^{2+}, NO_3^2 - Fe^{2+}, SO_4^{2-}- Cl^-, SO_4^{2-} - Na^+, SO_4^{2-} - K^+, Cl^- - Mg^{2+} and Cl^- - Ca^{2+} are also poor. Piper trilinear plotting was used in the study of the water chemistry and quality. Piper trilinear diagram is a graphical treatment of chemical analysis of groundwater developed by Piper in 1944. In the trilinear diagram, the character of groundwater can be expressed by three points located in three different fields. The points represent: (1) percentage-reacting equivalents of three major cation constituents (Mg^{2+}, Na^+ and Ca^{2+}) in a cation triangular field; (2) percentage equivalents of three major anion constituents (Cl^-, SO_4^{2-} and HCO_3^-) in an anion triangular field; and (3) the point in the diamond-shaped field representing the overall chemical character of the solution. The last point is plotted at the intersection of rays projected from the points in the anion and cation triangular fields into the diamond field (figure 4.1). Piper's graphical treatment of the chemical analysis allows for an easy discrimination of distinct water types by their plotting in various subareas of the diamond field and to identify the hydrochemical facies of groundwater in the study area (figure 4.2), which clearly explains the variation or domination of cation and anion concentration in the study area. Using the diamond field, groundwater can be divided into four basic types according to their placement near the four corners of the diamond. In the diamond field plotting, the locations plotted at the top of the diamond indicate water high in both Ca^{2+} + Mg^{2+} and Cl^-+ SO_4^{2+}. The locations plotted near the left corner shows water rich in Ca^{2+} + Mg^{2+} and HCO_3^-. Locations plotted at the lower corner of the diamond shows water primarily composed of alkali carbonates (Na^++ K^+ and HCO_3-+CO_3^{2-}). Locations plotted near the right-hand side of the diamond reveals water that may be considered saline (Na^++ K^+ and Cl^-+ SO_4^{2+}). Using this general grouping of groundwater, the water types in the study area were classified based on the area in which they occur on the .Using the subdivisions of the diamond shaped field of the piper diagram, the groundwater in the study area was characterized in order to identify the water composition in different classes based on the dominance of certain cations and anions in solutions (table 3.4). According to table 3.4 Alkali earth type of water ($Ca^{2+} + Mg^{2+}$) exceed the Alkalis ($Na^+ + K^+$) in all the samples except in sample 6 and 8. For the anions, the strong acids ($SO_4^{2-} + Cl^-$) exceed the weak acids ($HCO_3^- + CO_3^{2-}$) in all the samples except in sample 1 and 9. Result of the piper trilinear in the study area shows that two samples fall into section 5 of the diamond shape division, three samples fall into section 6, two samples fall into section 7, no sample occurred in section 8, and three plotted in section 9 of the `diamond shape division. The results were compared with Offodile (2014) in characterization of anionic and cationic concentration. It shows that the area is dominated with magnesium sulphate Using this classification, the groundwater in the area falls under the Magnesium sulphate ($Mg\text{-}SO_4^{2-}$) facies type.

Conclusion

Generally it has been recognized that groundwater quantity is as important as its quality. The groundwater quality profile of Elele and its environments has been highlighted by the collection of sample from ten functional boreholes and analyzed for different physical and chemical parameters using standard techniques for water resources investigation. In comparison with the standards such as WHO (2006) and NSDWQ (2007).

The analytical result shows that the water is low in dissolved constituent and potable. In essence the water is suitable for drinking and for other purposes. The concentration values of the various parameters determined for each of the water samples were relatively in harmony with the WHO (2006) and NSDWQ (2007) standard for domestic uses except for pH and Iron (Fe^{2+}). The concentration of pH was lower than the WHO (2006) specified standard in two locations. Fe^{2+} values were slightly above WHO standard in four locations. However, the high concentration of Fe^{2+} is not too pronounced to cause serious health hazards.

Trilinear plotting system was used in the study of the water chemistry and quality. The plotting showed that alkali earth type of water ($Ca^{2+} + Mg^{2+}$) exceed the alkalis ($Na^+ + K^+$) whereas for the anions, the strong acids ($SO_4^{2-} + Cl^-$) exceed weak acids ($HCO_3^- + CO_3^{2-}$).

Recommendation

Since pH values in the area show slightly acidic to slightly alkaline groundwater, polyvinyl chloride (PVC) pipes and other non-corrosive materials should be used for borehole construction in the area because acidic waters can be very aggressive Water in some of the study area should be treated for acidity using Basic Exchange Method with dolomite. The quality of water should be monitored on regular basis to detect possible future pollution of water. Proper documentation of borehole in the study area for history purposes should be done.

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