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ASPECTS OF SHALLOW GROUNDWATER QUALITY IN CALABAR SOUTH, CROSS RIVER STATE, NIGERIA

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ABSTRACT

This study aims at determining the quality for groundwater in the study area, for domestic and other uses. Water samples were collected in thirty plastic bottles of 1.5litres from fifteen functional boreholes in the study location. These samples were analyzed for physicochemical and bacteriological parameters using standard field and laboratory techniques. The dominant cations are Ca2+, K2+, Mg2+ and Na+ with mean composition of 27.20, 4.30, 89.50, and 33.00mg/l respectively. S042-, Cl-, P042- and N03-are dominant anions with respective mean values of 19.58, 3.22, 5.79 and 11.94mg/l. The highest recorded value for total hardness is 19.7mg/l revealed that the groundwater in the study location is soft, while concentration level of chloride (between 1.60 to 5.03 mg/l) with mean value 3.22mg/l shows absence of saltwater intrusion. Zinc and copper have values below WHO & NDWQ while for aluminum, less than 50% of the samples were above the standard. The iron concentrations at all location do not meet the WHO and NSDWQ standard for drinking water except for borehole location 11. The high iron should be treated with appropriate methods to reduce the concentration. The pH value should be treated to increase the pH to between 7 and 8 where this standard is not met. Further analysis of the groundwater chemistry to determine its suitability for agriculture or irrigation shows that the groundwater is excellently good for agriculture or irrigation purpose in the area. It is recommended that regular monitoring be carried out in the area.

KEYWORDS

Groundwater, borehole, water quality, aquifer, Calabar.

1. INTRODUCTION

In recent time, it has been recognized that the quality of ground water is as important as its quantity. Groundwater has been the major source of water supply for human consumption in the study area, so any change in its quality can have serious consequences on the inhabitants. Therefore, it becomes necessary to undertake baseline study of its status for understanding and predicting the impact of future development on the quality of the water.

Water quality is determined by its chemical composition and variability, whose assessment will depend on the envisage usage. Groundwater, being a major source of water for human consumption is very important in this regard. The present study aims at studying the physicochemical and bacteriological characteristic of groundwater and influence of these parameters on groundwater with a view to ascertain its suitability for domestic and other purposes, when compared with parameters of analyzed borehole samples and internationally acceptable standard, World Health Organization (WHO,2008) and locally standard, Nigerian standard for drinking water quality (NSDWQ, 2008) [1,2]. Two main rivers dominate the landscape of Calabar South Local Government Area, these are the Calabar river, a tributary of the Cross river, located on the West and the Great Qua river, which is located on the Eastern part of the study area (Fig.1).

Calabar south is one of the 18 Local Government Area that make up Cross River State. It is approximately located within latitudes $4^0 55'$N and $4^0 57'$N, and longitudes $8^0 18'$E and $8^0 21'$E. The headquarters of Calabar South Local Government Area is Anantigha, with major streets being Mbukpa, Musaha, Goldie, Edgerley, Akpanim, UduakOrok, EkpoAbasi and New Airport (fig 1). It occupies an area extent of about 287.303km2with a population of about 254,165 [3-5].

Physiographically, the study area is located at the boundary between the Niger Delta, the Cross River estuary and the south-eastern part of the Benue Trough. It is made up of tertiary to recent, continental fluvialite sands and clays which is called the coastal plan sand (Benin Formation) which overlain the study area. The Tertiary sand of the Benin Formation (Miocene – Recent) composed mostly, sand of medium to coarse-grain, moderately-sorted pebble, with local lenses of fine-grained, with poorly cemented sand and silty clay. This coastal plain sand is the most prolific aquiferous hydrogeological settings in the area. Discharging wells and water boreholes are located in this formation. Elevation of the area is less than 100 meters above the mean sea level. There is sand-shale intercalation in the area which suggests multi-aquifer system. The first aquifer is unconfirmed and generally exists throughout the entire area of study. It extends to depths of 60-70 meters (186-217ft) below the sea level, while the second one is more prolific and extends up to 150 meters (465ft) or more. The petrographic analysis of the area, Onyeagocha (1980) showed that the rocks are composed of about 95-99% quartz grains: Na+k, 1-2.5% mica, 0.5-1.0% feldspar and 2.3% dark coloured minerals, while a researcher contends that the composition, structure and grains size of the formation indicate deposition in continental environment [6-10].

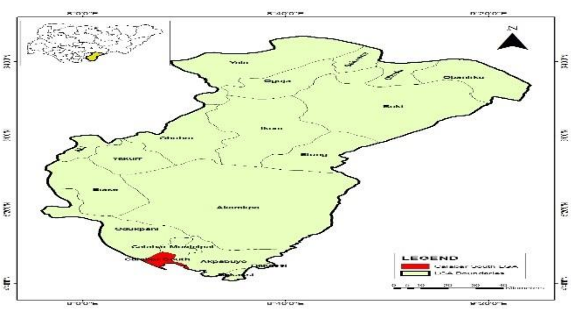

Figure 1: Map of Cross River State showing the study area (Calabar South LGA)

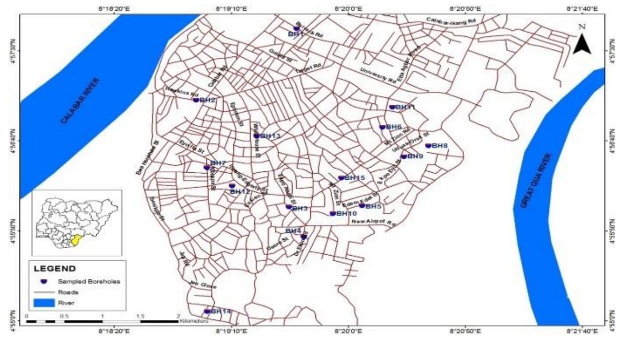

Figure 2: Map of Calabar South L.G.A. showing borehole sample locations.

2. METHODS OF STUDY

2.1 Sampling

Groundwater samples were collected in sterilized 1.5 litre plastic bottle. This was done just immediately when the wells were pumped for the period of five minutes in order to create allowance for adequate collections of representative sample at the well head of each of the sample boreholes. After the sampling of each, the bottle was capped straight away to reduce oxygen adulteration and the discharge of liquefied gases, suitably categorized just at the instance of assemblage and thereafter taken to the laboratory for analysis in an ice-packed cooler kit within 24 hours. Sampling was carried out at the time the weather was fair enough in order to avoid rain water so as not to affect the quality of the samples that were collected. Anion determination was carried out after acidification. Note, the choice of acid is hinged on the anion e.g. Iron in determination sample was primed with 0.5ml solution of nitric acid. This was done in order to keep the iron in solution.

The fact that the ground water chemistry is sensitive to environmental variations, the ensuing strictures were measured and documented in-situ: color, p^H, temperature and electrical conductivity, while the rest of the parameters were analyzed in the laboratory by means of a standard analytical method revealed in Table 1 while Table 2 shows the results.

Table 1: Summary of Analytical Methods Used

DETERMINATION	ANALYTICAL METHOD
Colour	LovibandNessleriser comparator
Temperature	Mercury in glass thermometer
P^H	P^H meter (Bromothymol/blue pH kit)
Turbidity	Turbidity meter
Conductivity and Dissolved Oxygen	Conductivity Meter
Total Dissolved Solids (TDS)	TDS Meter
Total Hardness, Iron, Chloride, Sulphate, Calcium, Zinc, Copper, Magnesium.	UV-Visible Spectrophotometer

Table 2: Result of Physico-Chemical and Bacteriological Data of Borehole in the Study Area

PARAMETERS / UNIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	WHO (2008)	NSDWQ (2008)
Colour (HU)	10.0	40.0	10.0	15.0	10.0	15.0	60.0	ND	ND	ND	ND	60	10	10	10	20	15 TCU
Temperature (°C)	26.9	26.8	27.2	26.9	26.8	26.6	26.8	26.6	26.7	26.8	26.9	26.6	26.6	26.9	26.9	Ambient	Ambient
P^H	4.64	6.42	7.03	6.83	6.86	6.85	5.45	4.13	4.46	3.81	4.14	5.21	6.33	5.56	4.12	6.5-8.5	6.5-8.5
Conductivity (µs/cm)	18.3	18.1	33	20.6	9.90	31.7	15.5	45.8	31.2	172.3	76.8	23.1	17.4	14.8	19.2	500	1000
Total Dissolved Solid (mg/l)	10.98	10.86	19.8	12.36	5.94	19.0	6.30	27.48	18.72	103.40	46.08	13.86	10.44	8.88	11.52	1000	500
Turbidity (NTU)	0.64	0.01	0.42	0.08	0.83	0.52	0.07	0.48	0.35	0.38	0.20	0.45	0.53	0.70	0.07	5.0	5.0
Dissolved Oxygen (mg/l)	12.0	7.0	14.0	9.0	4.40	14.0	11.0	12.0	15.0	14.0	13.0	11.0	8.0	10.0	12.0	14	
Salinity (ppt)	0.2	0.1	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	4.0	
Total Hardness (mg/l)	19.7	10.6	13.8	11.7	8.4	5.8	17.1	12.6	16.0	10.50	13.80	17.1	17.1	17.1	17.1	400	500
Alkalinity (mg/)	7.00	7.82	8.00	7.95	7.96	7.96	7.43	6.61	6.86	6.33	6.62	7.31	7.79	7.48	6.61	400	
Calcium Hardness (mg/l)	74.0	61.3	89.4	73.6	38.2	106.3	9.6	5.00	6.59	4.45	6.69	9.0	37.5	20.0	17.1	50	75
Magnesium Hardness (mg/l)	45.0	41.3	47.4	46.1	30.2	89.5	7.5	7.60	9.41	6.05	7.11	8.1	30.9	14.2	13.2	100	
Manganese (mg/l)	0.14	1.05	0.08	0.96	0.84	0.93	4.86	0.04	0.04	0.03	0.04	4.02	0.09	0.08	0.10	0.05	0.20
Iron (mg/l)	0.82	2.11	0.45	0.63	0.70	0.60	7.11	0.36	0.39	0.41	0.27	6.30	0.42	0.36	0.43	0.30	0.30
Sulphate (mg/l)	17.6	42.0	21.6	16.2	11.8	17.6	48.7	12.5	11.0	6.50	8.10	40.3	15.4	12.4	12.0	200	100
Chloride (mg/l)	2.90	4.01	2.40	5.00	5.03	5.01	2.33	2.60	3.06	1.60	4.30	1.80	3.10	3.10	2.04	250	250
Phosphate (mg/l)	5.0	6.3	6.0	6.9	6.16	5.30	7.80	5.14	6.02	4.55	7.20	4.46	6.50	4.27	5.30	200	
Sodium (mg/l)	3.10	2.04	2.01	3.12	2.46	33.0	1.51	1.02	1.30	0.96	1.80	0.90	1.80	2.60	1.20	200	200
Zinc (mg/l)	1.08	1.20	1.09	0.97	1.33	1.25	1.09	0.68	0.77	1.02	1.15	1.14	2.05	1.76	0.15	5.0	3.0
Copper (mg/l)	0.56	0.80	0.45	0.48	0.86	0.52	0.47	0.25	0.34	0.22	0.40	0.63	0.45	0.70	0.22	1.0	
Total Suspended solid (mg/l)	ND	2.07	ND	0.01	ND	0.01	8.01	ND	ND	ND	ND	7.090	ND	ND	ND	1.0	
Aluminum(mg/l)	0.30	0.12	0.12	0.05	0.12	0.30	0.24	0.36	0.40	0.40	0.40	0.18	0.15	0.17	0.02	0.20	0.20
Ammonium(mg/l)	1.20	1.0	1.0	1.3	1.0	1.3	1.2	0.36	0.40	0.40	0.40	1.2	1.0	0.8	0.5	0.50	
Potassium (mg/l)	3.30	3.50	4.60	4.30	2.20	3.90	1.80	5.60	4.21	8.02	10.40	3.50	4.20	1.50	3.60	200	
Nitrate (mg/l)	37.2	12.6	17.9	8.0	8.3	12.8	7.7	3.50	10.2	12.0	6.50	20.4	10.3	7.3	4.35	45	50
Nitrite (mg/l)	0.20	0.02	0.03	0.03	0.16	0.010	0.02	0.06	0.05	0.05	0.04	0.021	0.02	0.02	0.08	0.10	0.20
Total Coliform Count/100ml	205	179	194	208	164	188	180	41.0	96.0	43.0	66.0	176	190	101	99	0	10
Fecal Coliform count/100ml	108	113	136	140	101	126	120	27.0	34.0	31.0	40.0	104	134	66	75	0	0

ND = NOT DETECTED. (Note: Serial Numbers correspond to sample locations number fig.3)
KEY: Borehole locations: (1) NO. 9 Barracks Road (2) NO. 9 Hawkins Road. (3) NO. 4 EkpoAbasi Street. (4) NO. 5 Musaha Street. (5) NO. 4 EdemEdet Street. (6) NO. 28 AsuquoAbasi Mt Zion. (7) NO. 3 Mbukpa Street. (8) NO. 5 UduakOkoro Street (9) NO. 18 Akpanim Street. (10) NO. 2 St. Zion Lane. (11) NO. 176 Goldie Street by St. Zion Lane. (12) NO. 41 InyangEdgerley. (13) NO. 4 White House street. (14) NO. 2 EkpenyongAbasi New Airport. (15) NO. 36 Mt. Zion Street.

Table 3: Summary of Descriptive Statistics

Parameters/Units	N	Minimum	Maximum	Mean	Std. Deviation	WHO'S STD (2008)	NSDWQ (2008)
Colour (HU)	15	0.00	60.00	16.6667	20.14826	20	15 TCU
Temperature (°C)	15	26.60	27.20	26.8000	0.16475	Ambient	Ambient
P^H	15	3.81	7.03	5.4560	1.18583	6.5-8.5	6.5-8.5
Conductivity (µs/cm)	15	9.90	172.30	36.5133	41.05860	500	1000
Total Dissolved Solid (mg/l)	15	5.94	103.40	21.7080	24.76157	1000	500
Turbidity (NTU)	15	0.01	0.83	0.3820	0.25120	5.0	5.0
Dissolved Oxygen (mg/l)	15	4.40	15.00	11.0933	2.96924	14	
Salinity (ppt)	15	0.00	0.20	0 .0667	0.07237	4.0	
Total Hardness (mg/l)	15	5.80	19.70	13.8933	3.91069	400	500
Alkalinity (mg/)	15	6.33	8.00	7.3153	0.59637	400	
Calcium Hardness (mg/l)	15	4.45	106.30	37.2487	34.84127	50	75
Magnesium Hardness (mg/l)	15	6.05	89.50	26.9047	23.68400	100	
Manganese (mg/l)	15	0.03	4.86	0.8867	1.50329	0.05	0.20
Iron (mg/l)	15	0.27	7.11	1.4240	2.19436	0.30	0.30
Sulphate (mg/l)	15	6.50	48.70	19.5800	13.13916	200	100
Chloride (mg/l)	15	1.60	5.03	3.2187	1.17953	250	250
Phosphate (mg/l)	15	4.27	7.80	5.7933	1.04887	200	
Sodium (mg/l)	15	0.90	33.00	3.9213	8.07716	200	200
Zinc (mg/l)	15	0.15	2.05	1.1153	0.43390	5.0	3.0
Copper (mg/l)	15	0.22	0.86	0.4900	0.19643	1.0	
Total Suspended solid (mg/l)	15	0.00	8.01	1.1457	2.66041	1.0	
Aluminum (mg/l)	15	0.02	0.40	0.2220	0.13034	0.20	0.20
Ammonium (mg/l)	15	0.36	1.30	0.8707	0.36142	0.50	
Potassium (mg/l)	15	1.50	10.40	4.3087	2.30334	200	
Nitrate (mg/l)	15	3.50	37.20	11.9367	8.36136	45	50
Nitrite (mg/l)	15	0.01	0.20	0.0545	0.05612	0.1	0.20
Total Coliform Count/100ml	15	41.00	208.00	142.0000	60.54868	0	10
Fecal Coliform Count/100ml	15	27.00	140.00	90.3333	41.23394	0	0

The pH values in the study area range between 3.81-7.03 with mean value of 5.46. Electricity conductivity range from 9.90-172.30 $\mu s/cm$ and 36.51 $\mu s/cm$ as the value of the mean.

2.1.1 Colour (Hazen Units)

The colour index of the groundwater in the area is in the range of 10-60 Hazen units. Only 60% (that is 8 locations out of 15 locations) met WHO (2008) and NSDWQ (2008) highest desirable limit of 20 Hazen unit and 15 Hazen units, respectively. The rest of analyzed samples whose index value is above the standard limit should be treated.

The range of groundwater temperature in the study area lies between 26.60°C and 27.20°C with a mean temperature of 26.80°C. However, the WHO (2008) and the NSDWQ (2008) present no standard value for potable groundwater temperature.

The pH range of the study area is 3.81 to 7.03 and its mean value is 5.5. The pH value at most locations (Table 2) show acidic to slightly alkaline. The low pH value is caused by the presence of shale intercalations in Benin Formation and free carbondioxide ($C0_2$) from the atmosphere can also get into the underground water system thereby reducing the value of the pH of the water, in so doing increasing the acidity.

2.1.2 Electrical Conductivity (µs/cm)

The presence of dissolved inorganic solids could influence the water conductivity. The followings are arrays of some of the dissolved inorganic solids: Nitrate, chloride, phosphate, phosphate ions or sodium, calcium, iron, magnesium and aluminum ions (cations). The mean groundwater conductivity in the study area is 36.5μs/cm. The maximum value is 172.3 in location borehole 10 (2 Mt Zion lane) and the minimum value is 9.90 μs/cm in location borehole 5 (4 Edem Edet Street) Fig 1 and Table 2. The conductivity values are particularly important in water meant for irrigation (Todd, 1980). All the water from the sampled boreholes in the study area have conductivity values within permissible regulatory limits of the WHO (2008) and the NSDWQ (2008) which is 500µs/cm and 1000μs/cm respectively. The permissible electrical conductance for irrigation is 2000μs/cm [11-15].

2.1.3 Turbidity

Turbidity is a function of the transparency or visual clarity of water. Turbidity is used to describe water containing suspended particulate matter which interferes with the passage of light through it [16]. The amount of suspended particles in water is important when considering public water supplies. The three major reasons why water turbidity must be considered are Aesthetics, filterability and disinfection. Turbidity values for groundwater samples in the study area are between 0.83 NTU – 0.01 NTU with mean value of 0.38 NTU. The value is below the WHO (2008) and NSDWQ (2008) recommended value of 5.0NTU. It is also below the NTU median turbidity recommendation in order to achieve adequate terminal disinfection.

2.1.4 Dissolved oxygen concentration (DO)

The level of dissolved oxygen in water may serve as an indicator of the microbial oxygen in water. DO from the study area is between 4.40mg/l and 15.0mg/l, with a mean value of 11.09mg/l. 97% of the DO values in the sampled locations is below the WHO (2008) permissible value of 14.0mg/l for drinking water. It could also be deduced that bacteriological activities at all locations depleted the available DO.

2.1.5 Total Suspended Solid (TSS) in mg/l

The TSS concentration in the study area is between 0.005mg/l - 8.014mg/l. Borehole locations 4 and 6, that is 5 Musaha Street and 28 AsuquoAbasi by Mt Zion respectively meet the WHO (2008) permissible limit for potable water, while borehole 2, 7 and 12 (9 Howkins Road, 3 Mbukpa Street and 41 InyangEdgarley Street respectively) with values: 2.07mg/l, 8.02mg/l and 7.09mg/l respectively, is much more higher than the WHO (2008) permissible limit for potable water.

2.1.6 Total Dissolved Solid (mg/l)

Total dissolved solids (TDS) is measure of the sum total of all organic and inorganic solutes in water. The TDS concentration ranges from 103.4 mg/l to 5.94mg/l with mean value 21.70 mg/l within the study area. As a result of the low value of TDS in the study area, is an indication that, groundwater in the area is fresh. The TDS values can be correlated with conductivity values. Highest TDS value of 103.4mg/l and the lowest TDS value of 5.94mg/l were recorded in 2 Mt. Zion Lane (BH 10) and 4 EdemEdet Street (BH 5) respectively. These areas with the highest and lowest TDS values show corresponding highest and lowest conductivity values. The WHO (2008) and the NSDWQ (2008) permissible limit for TDS is 1000mg/l and 500mg/l respectively for potable drinking water. Thus, from results obtained, the groundwater samples are potable with respect to TDS. The water is also suitable for irrigation since it is not saline (greater than 100mg/l TDS) and according to Richards (1954), more than 1000mg/l TDS is good for industrial purposes like dying of textile and manufacture of pulp, paper, plastics and rayon.

2.1.7 Sodium and Potassium (mg/l)

Sodium concentration values for groundwater samples in the study location ranges between 0.90mg/l to 33.0mg/l, while potassium concentration ranges between 1.50mg/l to 10.40mg/l. These values are lower than the WHO and NSDWQ (2008) permissible limit of 200mg/l. This indicates that the portability of groundwater is determined by the parameter. Considering potassium ions, which originate from dissolution of feldspars during the weathering process, the element is generally important for plant and animals as its key for soil fertility.

Concentration of Ca^{2+} and Mg^{2+} in groundwater samples in the area lies between 106.3mg/l (BH6) to 4.45mg/l (BH10) and 89.5mg/l in BH6 TO 6.05mg/l in BH10 respectively. All the concentration of calcium as recorded is below recommended WHO and NSDQW limit of 50mg/l and 75mg/l respectively except borehole 6 sample (28 AsukwoAbasi Mt. zion) and Borehole 3 (4 EkpoAbasi Street) samples, with values of 106.3mg/l and 89.4mg/l respectively. Magnesium concentration of all the samples in the locations meets the standard limit of WHO. In 1980, Twort et al. established that excesses of calcium ions in form of calcium bicarbonate causes temporary hardness while excess of magnesium causes permanent hardness. High concentration of calcium in water tends to reduce the lathering effect of soaps and detergents [17-22].

2.1.8 Chloride, phosphate and Sulphate

The chloride concentrations from groundwater samples in the location ranges from 1.60mg/l to 5.03mg/l while the sulphate concentration is between 6.50mg/l and 48.7mg/l and the phosphate concentration is between 4.27mg/l and 7.80mg/l. Generally, concentration of chloride, sulphate and phosphate ions in the study area is far below WHO and NSDWQ(2008) standard limits for drinking water with the limits of 250mg/l, 200mg/l and 200mg/l for WHO(2008) and 250mg/l,100mg/l for NSDWQ(2008) respectively. This indicates that there is presence of low salts in the groundwater. Therefore, the water is suitable for domestic uses.

2.1.9 Salinity (ppt)

The groundwater salinity which was determined by electrical conductivity of the area, has values ranging from 0 to 0.2 (ppt) with a mean value of 0.07ppt, which met the WHO permissible limit of 4.0ppt for drinking water. The low salinity is also an advantage for irrigation water.

2.1.10Total Harness (mg/l)

Hard water is when water containing large quantities of dissolved salts example, calcium and magnesium ions. Groundwater hardness in the study area lies between the range of 5.8mg/l and 19.7mgl with a mean value of 13.89mg/l. The values are within the WHO (2008) and NSDWQ (2008) permissible limits of 400mg/l and 500mg/l respectively for potable water. This indicates that the groundwater in the study location is soft and potable for domestic consumption.

2.1.11 Alkalinity (mg/l)

This is the capacity of solutions to neutralize acid. In most natural water, the alkalinity is produced practically by dissolved carbonates and bicarbonates ions. The mean value of alkalinity in the study area is 7.32mg/l with maximum and minimum values of 8.00mg/l and 6.61mg/l respectively. The alkaline concentration of the area is far lower than the permissible limit of WHO (2008) for drinking water which is 400mg/l. This low value must have come from the high volume if infiltrated water which caused soil water accretion and a subsequent dilution of the aquifer.

2.1.12 Total Iron and Manganese (mg/l)

The concentration values for iron and manganese in the study area are from 7.11mg/l to 0.27mg/l and 4.86mg/l to 0.03mg/l respectively. The iron concentration in study area is above the recommended WHO (2008) and NSDWQ (2008) limit for potable water which is 0.3mg/l, except borehole 11 (176 Goldie street) with value 0.27mg/l, which is below the WHO (2008) and NSDWQ (2008) permissible limit for drinking water, while manganese concentration with values of 0.04mg/l, 0.04mg/l, 0.03mg/l and 0.04mg/l for borehole locations 8,9,10 and 11respectively, met the permissible limit of WHO (2008) and NSDWQ (2008) for drinking water which are 0.05mg/l and 0.20mg/l respectively. But borehole locations 1, 3, 13, 14 and 15 with concentrations of 0.14mg/l,0.08mg/l,0.09mg/l, 0.08mg/l and 0.10mg/l respectively met the NSDWQ (2008) permissible limit for potable water while locations borehole 2, 4,5,6,7 and 12 with values 1.05mg/l,0.96mg/l,0.84mg/l,0.93mg/l,4.86mg/l and 4.02mg/l respectively are above recommended WHO (2008) and NSWQ (2008) limit for potable water.

The higher value of iron in the area could cause stain plumbing fixtures and laundered clothes. thus iron should be treated in all the boreholes which concentration is above permissible limits (WHO) and NSDWQ (2008), also manganese concentration value that exceeds the WHO (2008) and NSDWQ (2008) permissible limit should be treated, as it could also stain plumbing fixtures and foster growths (incrustation) in reservoirs and in the distribution system. The high value of iron concentration in groundwater poses potential hazards for many industrial processes, such as high-pressure boiler feed water, process water, fabric dying, paper making, brewery, distillery, photographic film manufacture, ice making and food processing which required water that is almost completely iron free.

2.1.13 Zinc, Copper and Aluminum (mg/l)

The concentration of these metals of the analyzed samples in the study area lies between 2.05mg/l to 0.15mg/l, 0.86mg/l to 0.22mg/l and 0.40mg/l to 0.02mg/l respectively. The concentration of zinc, copper and aluminum permissible limit of WHO (2008) and NSDWQ (2008) are 5.0mg/l, 1.0mg/l and 0.20mg/l and 3.0mg/l, not determined (ND) and 0.20mg/l respectively. This means that zinc and copper concentrations falls below the WHO and NSDWQ (2008) permissible limit for potable water, which indicate that the water is good for domestic and industrial use. But the values of aluminum ion in the study area has more than 50% below the WHO and NSDWQ (2008) limit for potable water.

2.1.14 Biological Parameters

Water can be a transmitting medium for a variety of disease-causing organisms, some of which may be parasitic, disease causing organisms typically to come from human waste, as do some intestinal and many other parasites. Drinking infected water or skin contact with it can transmit the disease. Drinking contaminated well or surface water has been known to transmit typhoid fever, cholera, bacillary dysentery, and paratyphoid fever. All of these are caused by specific bacterium. Pathogenic organisms in drinking water can be removed by filtration and/or disinfection with chlorine or iodine. Shellfish from areas where sewage is discharged are unfit for consumption. Water contact should be avoided in areas of parasitic infection (Fetter, 1980).

2.1.15 Total Caliform Count and FeacalCaliform Count/100ml

Total caliform count refers to a group of bacteria used to indicate the potential presence of harmful bacteria in water, resulting from human and animal wastes. Feacalcaliforms count provides a direct means of measuring human and animal waste inputs. Groundwater samples analyzed for microbial content shows a very high concentration of both counts in the study area. The values ranges from 208 count/100ml to 41.0 count/100ml and 140.0 count/100ml to 27.0 count/100ml respectively. The highest values mostly are from boreholes 4, 1, 3 and 13 and boreholes 4,3,13 and 6, that is (#5 Musaha street, #9 Barracks road, #4 EkpoAbasi street and #4 white house street) and (#5 Musaha street, #4 EkpoAbasi Street, #4 white house street and #28 AsuquoAbasi Mt. Zion) respectively. Generally, the high values of caliform in the study area exceed the WHO and NSDWQ (2008) permissible limits of nil count/100ml and 10count/100ml respectively and therefore it is unsafe for drinking.

2.1.16 Correlation Matrices

In order to assess the relationship between two variables correlation coefficient method is employed. This in turn shows by what means one variable envisages the other [7]. A correlation coefficient (r) of +1 portrays that two variables are flawlessly interconnected in a linear sense positively, but r = -1 indicates a negative linear correlation. Conversely, no relationship between two variables exists if r = 0. Consequently, two variables with a positive correlation coefficient mean that they have a fundamental origin, while negative correlation coefficient designates dissimilar sources.

Very strong positive significant correlation exists amid EC and TDS (r =1.00). For pH and Cl (r =0.575), K and EC (r =0.749), K and TDS (r =0.754), Ca and Cl (r =0.504), Alk and NH4 (r =0.794), SO4 and Mn (r =0.884), SO4 and Fe (r =0.876), Ca and Mg (r =0.962), Mn and Fe (r =0.979), Ca and Salinity (r =0.729) and between Zn and Cu (r =0.546). Other significant positive correlations also exist as seen in Table 4. The movement proposes that the pairs of affected ions takes its source from mutual natural and anthropogenic bases into the groundwater. Also, negative correlations exist between EC - pH (r = -0.514), Al-pH (r = -0.58), EC-Cu (r = -0.522), NH4-K (r = - 0.577), DO-Alk (r = -0.52), Al-Alk (r = -0.594) and between Alk-TDS (r = -0.597).

2.1.17 Schoeller Diagram

The Schoeller diagrams shows a decreasing flow path in the Cl^- and K^+ ion present in all the water samples, with Na^+ relatively having least concentrations of ions composition of the water. There is an increasing flow in the Ca^{2+}, Mg^{2+} and $SO4^{2-}$ present in the water. This implies that the major ions present in the water are the Ca^{2+}, Mg^{2+} and $SO4^{2-}$, hence the dominant water type.

Table 4: Correlation matri

	pH	EC	TDS	Turb	DO	TH	Alk	Salinity	Ca	Mg	Mn	Fe	Cl	Na	Zn	Cu	SO4	PO4	Al	NH4	K	NO4	NO3
pH	1																						
EC	-0.514	1																					
TDS	-0.511	1.00**	1																				
Turb	0.145	-0.076	-0.065	1																			
DO	-0.502	0.454	0.452	-0.14	1																		
TH	-0.411	-0.271	-0.277	-0.04	0.137	1																	
Alk	.99**	-.598*	-.597*	0.154	-.52*	-0.31	1																
Salinity	0.381	0.03	0.038	0.204	0.102	0.022	0.36	1															
Ca	.73**	-0.318	-0.31	0.102	-0.06	-0.37	.699**	.729**	1														
Mg	.70**	-0.292	-0.284	0.148	-0.05	-0.49	.675**	.599*	.962**	1													
Mn	0.143	-0.254	-0.276	-0.26	-0.15	0.15	0.216	-0.347	-0.166	-0.153	1												
Fe	0.03	-0.219	-0.24	-0.27	-0.10	0.279	0.113	-0.322	-0.248	-0.256	.979**	1											
Cl	.575*	-0.309	-0.301	0.086	-0.42	-.60*	.549*	0.02	0.504	.586*	-0.184	-0.331	1										
Na	0.371	-0.07	-0.067	0.171	0.232	-.57*	0.346	0.177	.601*	.774**	-0.012	-0.13	0.473	1									
Zn	0.494	-0.135	-0.133	0.481	-0.42	-0.01	.533*	0.327	0.184	0.215	0.025	0.011	0.269	0.118	1								
Cu	.635*	-.522*	-.519*	0.338	-0.7*	-0.17	.688**	0.146	0.338	0.324	0.263	0.226	0.491	0.091	.546*	1							
SO4	0.289	-0.383	-0.401	-0.39	-0.22	0.162	0.365	-0.055	0.072	0.029	.844**	.876**	-0.17	-0.05	0.074	0.399	1						
PO4	0.29	-0.226	-0.241	-0.51	-0.23	-0.05	0.29	-0.199	0.06	0.03	0.255	0.195	0.4	-0.11	0.057	0.032	0.275	1					
Al	-.58*	.584*	.580*	0.161	.597*	-0.06	-.594*	-0.144	-0.337	-0.239	-0.135	-0.091	-0.13	0.133	-0.04	-0.38	-0.26	-0.10	1				
NH4	.74**	-.540*	-.545*	0.089	-0.37	-0.06	.794**	0.408	.671**	.644**	.517*	0.434	0.331	0.375	0.394	.600*	.566*	0.169	-0.477	1			
K	-0.47	.749**	.754**	-0.23	0.443	-0.20	-.550*	-0.08	-0.234	-0.221	-0.381	-0.351	-0.02	-0.07	-0.17	-.54*	-0.44	0.105	.559*	-.577*	1		
NO4	0.04	-0.079	-0.074	0.304	0.146	0.311	0.085	.635*	0.434	0.337	0.058	0.127	-0.17	0.059	0.12	0.245	0.197	-0.30	0.094	0.458	-0.142	1	
NO3	-0.17	-0.099	-0.093	0.447	-0.20	0.125	-0.175	0.13	0.085	0.028	-0.257	-0.243	0.077	-0.18	-0.20	0.168	-0.30	-0.16	0.027	0	-0.132	0.47	1

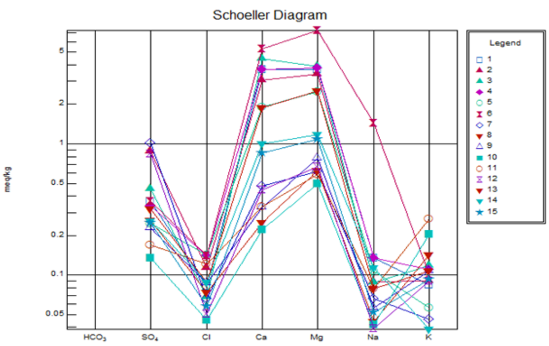

Figure 6: Schoeller diagram

3. CONCLUSION

The result indicates that the groundwater is potable and appropriate for domestic consumption and other purposes. However, the concentration of iron which values are very high throughout the sampled locations; except borehole eleven (BH 11) which is 176 Goldie Street by Mt. Zion Lane), with a value of 0.27mg/l, that meet the WHO and NSDWQ (2008) permissible limit for potable water. The underground water in the area is to some extent slightly acidic to slightly alkaline in nature due to the pH concentration and the water is soft, indicating low in salinity, alkalinity and hardness. The groundwater is fresh due to low concentration of chloride, sulphate and phosphate, indicates absence of salt water encroachment in the specified area. The concentration of bacteriological parameter (total caliform and feacal coliform) in the groundwater is higher than WHO and NSDWQ (2008) permissible limit of nil count/100ml and 10 count/100ml respectively. This high value makes the groundwater unsafe for drinking and poses great risk of diseases and stomach disorder when consumed.

Hydrochemical study of groundwater in Calabar South Local Government Area shows that the underground water in the study area is soft, fresh and appropriate for domestic as well as industrial, irrigation or agricultural and other purposes, particularly when treated for iron and acidity. Iron concentration in all samples location in the study area is higher than WHO and NSDWQ (2008) permissible limit. Treatment is recommended to get rid of this concentration. The examined samples in the study area shows that electrical conductivity (EC) and total dissolved solid (TDS) concentrations meet the WHO and NSDWQ (2008) permissible limit for domestic consumption and other purposes.Microbial analysis of the water samples indicates the presence of high concentration of total faecal coliform, showing anthropogenic contamination of groundwater.

Acidic waters can be very aggressive, therefore low p^H less than 6.5mg/l makes water inappropriate particularly for drinking purposes, but it can be treated with lime before usage. PVC pipes and other non-corrosive materials should be used for well construction due to high iron concentration. Moreso, the water should be treated to prevent iron bacteria which cause incrustation and corrosion of pipes. Borehole drillers should always leave information on the borehole history with their clients. Boreholes should be sited away from waste dump sites and further monitoring of boreholes in the area should be carried out.

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