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SEASONAL VARIATION IN THE PHYSICO-CHEMICAL AND BACTERIOLOGICAL CHARACTERISTICS OF PERCHED AQUIFER WATER FROM ZARIA, NORTH-CENTRAL NIGERIA

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Abstract

The seasonal changes in the physiochemical and bacteriological characteristics of groundwater from perched aquifers in Zaria, Kaduna State was studied. Groundwater from hand-dug wells were sampled during the rainy and dry seasons from Samaru and Sabon-gari areas of Zaria and the relevant physical, chemical and bacteriological parameters were analyzed in the laboratory. The results indicated that all the parameters had higher values in the dry season compared with the rainy season except for electrical conductivity, which increased from 1210 μS/cm in the dry season to 1913 μS/cm in the rainy season. The chemical parameters except calcium and chloride were greater than the World Health Organization and Nigerian Standard for Drinking Water Quality maximum permissible limits for safe drinking water in the dry season. The reverse was the case for the rainy season except for the bacteria count. The values of the bacteria counts were higher in dry season than in rainy season due to dilution effect. These results imply that water from the perched aquifers in Samaru and Sabon-gari need to be boiled before used for domestic purposes in the dry season but are good for agricultural purposes. Water for drinking and domestic purposes should be sourced from deeper aquifers through boreholes and the people in the area should maintain a better environmental sanitation practice.

***Keywords:** Seasonal Changes, Water Quality, Perched Aquifers and Zaria*

Introduction

Groundwater quality appraisal is an essential tool in effective water management. A major characteristic of groundwater is the constancy of its physio-chemical and bacteriological properties irrespective of season (Olasehinde, et. al, 1998). The prevailing climatic conditions and sanitary system in an area affects the quality of groundwater in the area (Adekeye and Ishaku, 2004). It has been observed that water supply for domestic and agricultural purpose in Zaria area is mainly from perched aquifer and surface water sources Whereas some perched aquifers have connections and same properties with the permanent aquifer through infiltration, others are isolated. This objective of the present study is to determine the groundwater quality as well as the seasonal variations in physico-chemical and bacteriological properties of the perched aquifer system. The rampant outbreak of water borne diseases such as (cholera, typhoid meningitis and diarrhea) in the area necessitated this study. It is also aimed at providing useful information for groundwater monitoring and management in the area.

Study Area

The study area comprises of Samaru and Sabon-gari areas in Zaria, which falls within the Sabon-gari local Government Area of Kaduna State (Fig. 1). It is located between longitude 7°13'E to 7°41'E and latitude 10°30'N to 10°52'N. The area is situated on the undifferentiated Precambrian Basement rock of granitic and metamorphic origin (*Ajibade and Wright, 1988; Ologe, 2002*). The geological mapping carried out reveals that rocks in the area consists of majorly porphyritic biotite granite, followed by porphyritic hornblende granite, diorite with gneiss and meta-sediments occurring occasionally (Mc-Curry, 1976). These rocks represent the deeper fractured aquifer which is partly overlain by the shallow porous aquifer (Annor and Olasehinde, 1996).

Climate and Physiography of the area

The area is relatively plain but varies in height from 1800m to 2350m above sea level reflecting the regional slope to the south while local relief of 120m to 180m above sea level also exist (Adekeye and Ishaku, 2004). The area is mainly drained in the south by the NW-SE flowing River Kubanni which joints the N-S flowing River Galma to discharge at River Kaduna (fig.1). The groundwater flow direction is from NW-SE parallel to the flow of River Kubanni. The area falls within the tropical savanna climate according to Koppen's climatic classification, with distinct rainy (wet) and dry season. The daily mean maximum temperature rises gradually to the peak in April (with some days having a temperature of about 40°C) but drops rapidly to about 26°C in August. The minimum temperature occurs around December with a temperature of about 11°C (*Ajibade and Wright, 1988*). The mean annual rainfall stands at about 1100 mm (*Adekeye and Ishaku, 2004).*

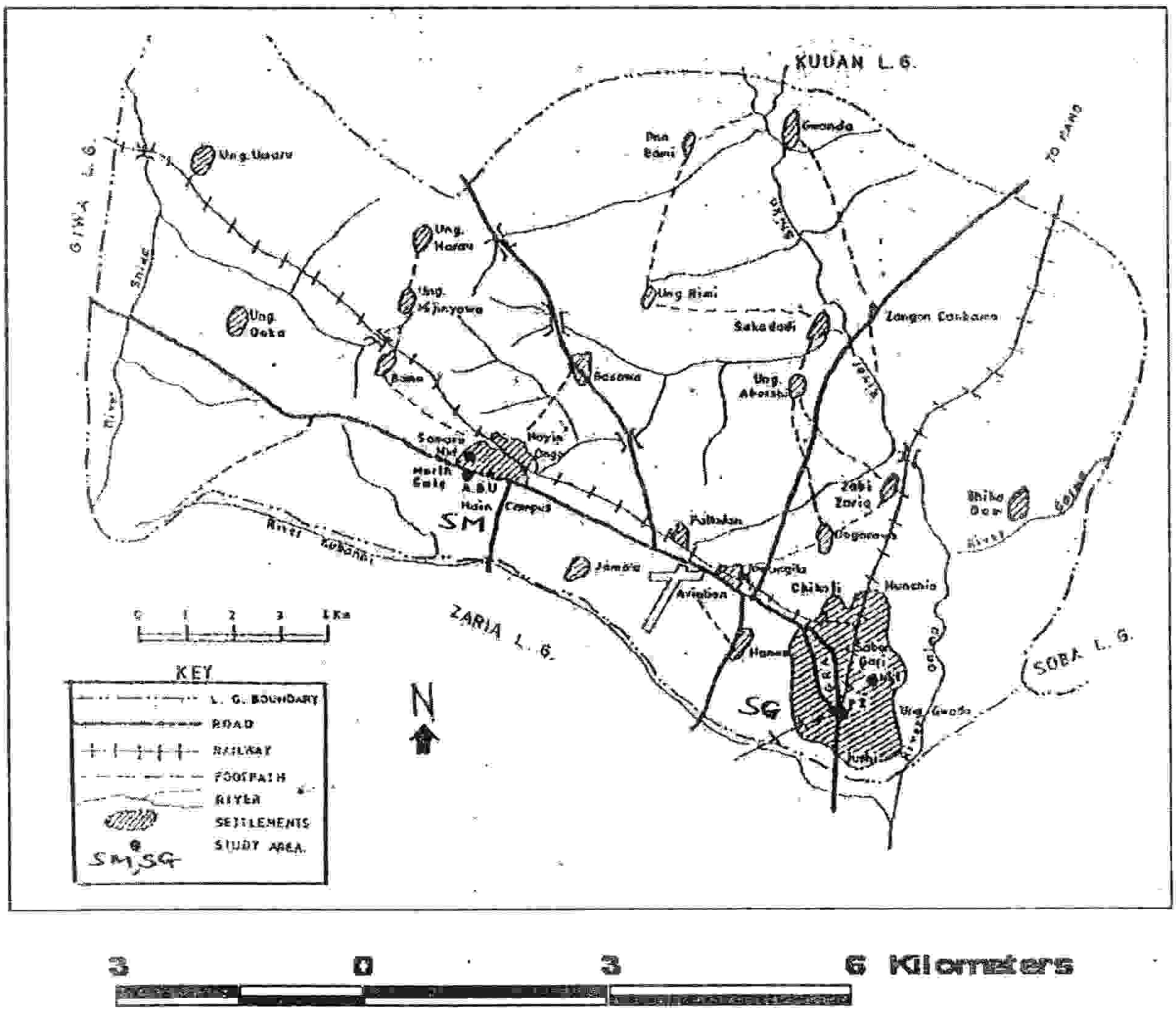

Fig. 1: Map of Sabon-Gari L. G. A. showing the study area location (After Mc-Cury, 1976).

Research Methodology

Sampling

Groundwater samples were collected from hand-dug wells in Samaru (SM) and Sabon-gari (SG) areas of Zaria and sent to the laboratory for relevant physico-chemical and bacteriological analyses using standard procedures for both physio-chemical (Dunlap et al., 1977) and microbiological variables (Fredrickson and Phelps, 1997). The physical parameters (pH, conductivity, colour and turbidity) were determined on the field using a calibrated pH meter, conductivity meter, true colour unit and turbidometer respectively. The chemical parameters (cations and anions) were analyzed using Atomic Absorption Spectrometer (AAS) and Flame Photometer respectively. The concentration of the trace elements were analyzed using ICP-OES (Inductive Coupled Plasma Atom Emission Spectrometry, Spectro Ciros CCD) while bacteriological counts were carried out using presumptive count. The groundwater samples for microbial test were stored in polyurethane bottles (pre-washed in 5% HCl and distilled water) and kept in the dark at 4°C before proceeding to the laboratory for analysis.

Results and Discussion

The results of the physical, chemical and bacteriological studies are shown in Tables 1 and 2 for dry and rainy seasons respectively while Table 3 indicates the average summary of the two seasons (dry and rainy respectively).

Physical Characteristics

The pH is a function of the dissolved material in water and ranges from 6.5 to 8.5 (WHO, 2006; NSDWQ, 2007). In the dry season, the range of pH values is between 6.5 and 6.9 except in Samaru area (SM-3) which has a pH value of 7.8. In the rainy season, the pH varies from 6.2 to 6.9. This implies that the waters are slightly more acidic in the dry season than in the rainy season due to the dilution effect by rainfall. The electrical conductivity (EC) is a function of dissolved solid in the water.

Table 1: Summary of the laboratory analysis of hand-dug well in Samaru (SM) and Sabon-gari (SG) during the Wet (Rainy) Season

Parameter	WHO STD	SM-1	SM-2	SM-3	SM-4	SM-5	SM-6	SG-1	SG-2	SG-3	SG-4	SG-5	SG-6
pH	6.5-8.5	6.4	6.5	6.9	6.22	6.4	6.3	6.8	6.5	6.6	6.5	6.5	6.8
Turbidity	5	30	35	90	70	72	75	19.75	65.25	72	30.5	20.25	95.25
Colour	5	5	5	5	5	5	5	5	5	8.75	5	5	12.5
EC	0	1250	1050	4000	1850	2500	1300	1803	1739	1882	1871	1878	1832
Ca^{+2}	200	83	85	102	35	21	98	22.25	14.75	63.25	48	18.5	19.75
Mg^{+2}	150	ND	ND	ND	ND	ND	ND	39.75	18	21.5	27.75	11.5	133.75
Fe^{+3}	0.1	2	2	2	2	2	2	2.5	2.5	2.5	3.5	2.5	2.5
NH_3N	0.5	0.15	0.12	0.125	0.3	1	0.3	0.02	0.05	0.02	0.02	0.39	0.5
Cr^{6+}	0.005	0.393	0.345	0.328	0.125	0.175	0.35	0.185	0.268	0.138	0.268	0.09	0.228
Cl^-	250	14	16	16.8	22	12.5	15	7.5	14.7	14.3	7.1	17.6	6.7
NO_3^-	50	15	18	20	30	15	20	29.75	52.25	20.5	34.3	69.5	43.25
Alkalinity	60	13[illegible]	125	760	135	140	90	56	29.25	95.25	35.25	35	81.25
TH	100	25	28	60	52	35.5	42	62	32.75	84.75	75.75	30	53.5
BOD	6	1.5	1.45	1.78	7.5	0.9	1.2	0.93	1.08	0.58	2.1	2.23	1.08
BC	10	3850	3790	78,500	470,000	28,000	10,800	325	1,100	5,225	1,500	5,300	2,725
DO	0.5	0.8	0.4	0.19	0.2	1.8	1.6	N.D	N.D	N.D	N.D	N.D	N.D

EC- Electrical Conductivity, BOD- Biochemical Oxygen Demand, DO- Dissolved Oxygen, TH-total hardness, ND- Not Determined, BC-Bacteria count- cfu/100ml, others- mg/L.
WHO- World Health Organization (2006) Standard for Drinking Water Quality
Units: Electrical Conductivity- mmhos/cm, Colour- TCU, Turbidity- NTU.

The EC has an average value of 1210.4μS/cm in the dry season but rose to 1913μS/cm in the rainy season. This is an indication of increase in total dissolved solid (TDS) in the rainy season. There is a general high mineralization of the base-flow and overland-flow waters in the catchment area. The approximate values of TDS can be obtained by multiplying the conductivity values value by a factor of 0.65 (Holting, 1984; Olasehinde, et. al., 1998). The turbidity values are generally high with the dry season having an average of 68.8 NTU while the rainy season has a mean value of 62.2 NTU for Samaru area. The dry season average of 25.0 NTU for Sabon-gari area seems doubtful for the dry season but the mean value of 50.5 NTU for rainy season is acceptable. The colour has a value of 5.0-12.5 TCU with an average of 7.2 TCU which dropped during the rainy season to an average of 5.9 TCU though the range of 5.0-12.5 TCU is maintained. This is a reflection of increase in pollution during dry season while the rainfall in rainy season helps to weaken the concentration of the contaminants, which is revealed by their lower values. The spatial variation from west to east of the study area is noticeable. In Samaru area (west) the average colour value is 5.0 NTU while in Sabon-gari area (east), colour has a mean value of 6.9 NTU. This trend is applicable to other parameters as well as for the two seasons under investigation. Dissolved Oxygen (DO) represents the amount of oxygen required to oxidize the organic matter content in the water samples to carbon-dioxide and water (Ademoroti, 1996). This was determined for Samaru area (west) with an average value of 1.33 mg/l for dry season and 0.83 mg/l for rainy season. The biochemical oxygen demand (BOD) is the amount of oxygen that bacteria will consume while decomposing organic matter into carbon-dioxide, water and Ammonia (Fredrickson and Phelps, 1997). The BOD has values of 1.5mg/l to 2.93mg/l, lower than the WHO, (2006) and NSDWQ, (2007) standards except at location SM-4 that has a value of 8.20mg/l. The average BOD is 2.62mg/l for dry season and 1.86 mg/l for rainy season. This means that the organic matter is not high in the water samples.

Table 2: Summary of the laboratory analysis of hand-dug well in Samaru (SM) and Sabon-gari (SG) during the dry Season

PARAMETER	WHO	SM-1	SM-2	SM-3	SM-4	SM-5	SM-6	SG-1	SG-2	SG-3	SG-4	SG-5	SG-6
Ph	6.5-8.5	6.6	6.7	7.8	6.5	6.5	6.8	6.9	6.6	6.7	6.7	6.8	6.9
Turbidity	5	32	38	98	72	95	78	1.4	1.6	2.9	3.1	2.6	3.4
Colour	5	5	5	10	5	5	5	7.5	6.3	12.5	5	7.5	12.5
EC	0	976	879	3589	1346	1050	900	1320.3	823.8	990.5	922.4	994	734
Ca^{+2}	200	25	20	72	80	23	25	73.3	84.8	101.1	30.2	17.1	89.5
Mg^{+4}	150	N.D	N.D	N.D	N.D	N.D	N.D	54	48.5	45.63	78.58	67.88	113.75
Fe^{+3}	0.1	3.5	3.2	3.5	3.2	3.1	2.25	3.5	3	2.5	3	3.5	2.5
$NH_3.N$	0.5	0.26	0.24	0.25	0.65	1.5	0.6	0.253	0.055	0.045	0.04	0.36	0.553
Cr^{6+}	0.05	0.26	0.26	0.105	0.213	0.08	0.218	0.418	0.163	0.155	0.135	0.135	0.35
Cl^-	250	7.4	8.64	8.35	11.5	6.44	5.73	14.83	28	26.75	28.85	28.85	23.56
NO_3	50	20	30	10	10	20	10	23.13	17	51.5	67	67	26.25
Alkalinity	60	149	145	784	149	145	98	72.75	105.25	172.25	92	92	171.25
TH	100	70.7	80.8	100.2	101	80.8	90.9	127.25	133.25	146.75	85	85	203.25
BOD	6	1.75	1.63	2	8.2	1.3	1.5	1.4	2.93	2.93	2.61	2.61	3.4
BC	10	4000	3925	800,000	490,000	30,000	11,000	875	2,625	2,975	2,800	2,800	3,050
DO	0.5	1	0.6	2.1	0.3	2.1	1.9	N.D	N.D	N.D	N.D	N.D	N.D

EC- Electrical Conductivity, TH- Total Hardness, BOD- Biochemical Oxygen Demand,
BC- Bacteria Count, DO- Dissolved Oxygen, ND- Not Determined,
WHO- World Health Organization (2006) Standard for Drinking Water Quality
Units: Electrical Conductivity- mmhos/cm, Colour- TCU, Turbidity- NTU,
Bacteria count- cfu/100ml, others- mg/L.

Bacteriological Characteristics

The bacteriological parameter determined was the bacteria count (cfu/100ml). The counts are very high in the whole area which is a reflection of poor sanitary practice in the area. The values of the bacteria counts have exceeded pollution level. The WHO (2006) and NSDWQ (2007) recommended a maximum allowable value of 10 cfu/100ml for a safe drinking water against average values of 112.67 cfu/100ml for dry season and 109,800 cfu/100ml for rainy season. In this study, this is a clear indication of faecal contamination of water sources in the area. Faecal indicator bacteria are universally present in high numbers in the faeces of humans and warm-blooded animals and causes urinary tract infection like meningitis and diarrhea as well as morbidity and mortality among children (Amadi, 2009). It also causes acute renal failure and hemolytic anemia in adults. Majority of the hand-dug wells sampled were unlined and they are sited close to unlined pit-latrine. This enhances easy migration of pollutants from the pit-latrine into the nearby well thereby contaminating the well. This may be responsible for the rampant outbreak of cholera, typhoid and other water borne diseases in Zaria area (Okuofu, et al., 1990).

Chemical Characteristics

The alkaline earth metal such as calcium has average values of 53.4 mg/l during the dry season and 50.9 mg/l during the rainy season (Table 3). The WHO permissible limit of 75 mg/l is higher than the measured concentration. This is expected for basement complex terrain due to the influence of the local geology on the water quality (Olasehinde and Amadi, 2009). The chloride content was low with mean values of 16.70 mg/l and 13.68 mg/l for dry and rainy seasons respectively as against 250 mg/l permissible limits given by WHO and 200 mg/l by NSDWQ. It implies that there is a low concentration of soluble salts underground through which the groundwater flows. The nitrogen compounds (nitrate and ammonia) are present in concentration lower than the WHO recommended value. Nitrate has a mean value of 26.64 mg/l for dry season and 15.48 mg/l for rainy season as against 50 mg/l by WHO (2006). In addition, ammonia has an average concentration of 0.4 mg/l for dry season and 0.25 mg/l for rainy season which are below the guideline value of 0.5 mg/l by NSDWQ (2007). The Fe^{3+} concentration of 3.5 mg/l is higher than the WHO and NSDWQ guideline value of 0.3 mg/l. For dry season, the Fe^{3+} concentration was 3.1 mg/l while it dropped to 2.3 mg/l during rainy season. The high value of Fe^{3+} could have been as a result of the occurance of laterite, which is enriched in Fe. The iron in groundwater is believed to have been leached from thick lateritic overburden in theinto the shallow water table below in addition to the chemical weathering of the host rocks. Total hardness of 110.72 mg/l is higher than the WHO guideline value of 100 mg/l in the dry season. This may not be widespread as high values are restricted to Sabon-gari area, which is dominated by feldspar-rich rocks. The values dropped to 48.48 mg/l in rainy season. Alkalinity value of 60 mg/l recommended for a safe drinking water has been exceeded in most of the water samples particularly in the western part (Samaru Area) while the values reduces considerably towards the eastern part (Sabon-gari area).

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Table 3: Average concentration of parameter analyzed in Samaru (SM) and Sabon-gari (SG) for both Dry and Wet (Rainy) Season

parameter	WHO-STD	S-M	S-G	Average	S-M	S-G	Average	Remarks
pH	6.5-8.5	6.8	6.8	6.8	6.5	6.6	6.6	Higher than wet
Turbidity	5	68.8	25	46.9	62	50.5	56.3	Higher than wet
Colour	5	5.8	8.6	7.2	5	6.9	5.9	Higher than wet
E.C	0	1456.7	0.1	1210.4	1992	1834	1913	Lower than wet
Ca^{+2}	75	40.8	66	53.4	70.7	31.1	50.9	Higher than wet
Mg^{+2}	30	N.D	68.1	N.D	N.D	25.4	N.D	————
Fe^{+3}	0.1	3.1	3	3.1	2	2.7	2.3	Higher than wet
NH_3.N.	0.5	0.58	0.22	0.4	0.33	0.18	0.25	Higher than wet
Cr^{6+}	0.05	0.19	0.23	0.21	0.29	0.19	0.24	Constant
Cl^-	200	8.01	25.3	16.7	16.05	11.32	13.68	Higher than wet
No_3	50	16.67	36.61	26.64	19.67	11.32	15.49	Higher than wet
Alkalinity	60	245	123.5	184.3	230	55.33	142.67	Higher than wet
TH	100	87.4	134.04	110.72	40.5	56.56	48.48	Higher than wet
BOD	6	2.73	2.51	2.62	2.39	1.33	1.86	Higher than wet
BC	10	223,154	2,200	112,677	216,906	2,696	109.800	Higher than wet
DO	0.5	1.33	N.D	N.D	0.83	N.D	N.D	Higher than wet

EC- Electrical Conductivity, TH- Total Hardness, BOD- Biochemical Oxygen Demand, BC- Bacteria Count, DO- Dissolved Oxygen, ND- Not Determined, WHO- World Health Organization (2006) Standard for Drinking Water Quality
Units: Electrical Conductivity- mmhos/cm, Colour- TCU, Turbidity- NTU, Bacteria count- cfu/100ml, others- mg/L.

Trilinear diagram.

The concentration of eight major ions (Na^+ ,K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, HCO^-_3 and SO_4^{2-}) are represented on a trilinear diagram by grouping the (K^+ with Na^+) and the (CO_3^{2-} with HCO^-_3), thus reducing the number of parameters for plotting to six. On the trilinear diagram, the relative concentration of the cations and anions are plotted in the lower triangles, and the resulting two points are extended into the central field to represent the total ion concentration (Fig. 2). The trilinear diagram is useful in classifying the hydro-chemical facies of the water samples according to their dominant ions. The water in the area is predominantly HCO_3^- and SO_4^{2-} type.

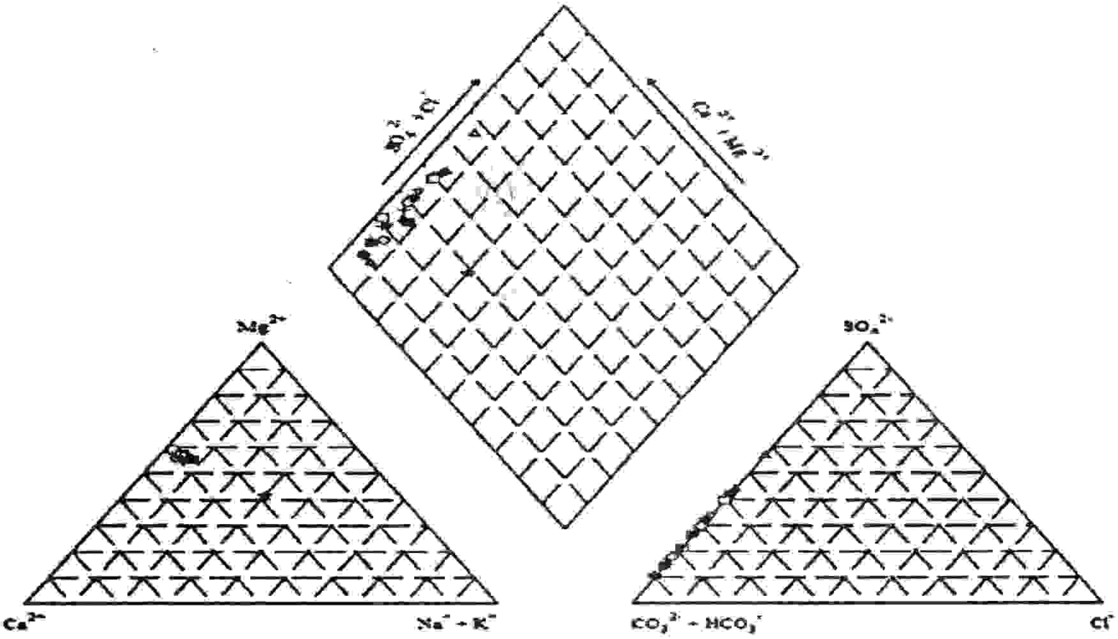

Fig. 2: Piper diagram of the Hand-dug wells.

Conclusion and Recommendation

The groundwater in the area is generally poor physically, worse bacteriologically but fair chemically. The fact that the concentrations of the parameters are higher in the dry season than in the rainy season makes the water better in the rainy season that in the dry season. The dilution effect of rain water in the shallow aquifer lowers the concentration. At the same time, the solubility of dissolved solutes increases in the rainy season thus increasing the electrical conductivity. It is observed that all parameters have higher concentration in the dry season than in the rainy season except electrical conductivity and Fe^{3+}. The water is slightly acidic and based on the dominant hydrochemical facies, the water type in the area is calcium-chloride type. The high turbidity, colour and conductivity values in both seasons render the water unfit for drinking and domestic purposes. However, these physical parameters can be improved by appropriate treatment like boiling and infiltration. Due to the high bacteria count in the water, boiling of the water is recommended. This is because bacteria cannot withstand high temperatures. The high Fe^{3+} renders the taste and colour less acceptable, therefore aeration of the water is recommended.

It is recommended that deeper groundwater sources (Boreholes) be provided for the citizens for domestic purposes. Water from surface and perched aquifer (hand-dug well) are useful for agricultural purposes whether in the dry or rainy season. Irrigated agriculture using hand-dug wells has been thriving in the area but the health implication of the perched aquifer water in the area needs urgent attention.

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