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Hydrogeochemistry of Some Selected Springs' Waters in Ekiti Basement Complex Area, Southwestern Nigeria

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ABSTRACT

The occurrence of surface water and shallow groundwater in Ekiti Basement area is erratic and subject to seasonal variation while the eleven selected springs under study have history of continuous yield throughout the year. Hence, this study aimed at assessing the hydrochemistry of the selected springs with a view to understand their hydrochemical evolution and suitability for domestic and irrigation purposes. Temperature, pH and EC of water samples from the springs were measured in the field using Schott electric conductometer. Subsequently, 30 springs' water samples were collected in polyethylene bottles and analysed in the Laboratory for cations and anions determinations using Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer and colorimetric method respectively. Results of the analyses indicate that pH of the springs' water range from 5.7 – 11.5 exceeding approved World Health Organisation (WHO) standard for drinking water in few locations. The EC range from 19 - 239µS/cm while the TH of 90% of the springs' waters is less than 70mg/L signifying soft, low mineralized water with no pronounced effects of rock-water interaction arising from transient residence time. Ionic concentrations in the springs' waters exhibiting trend of $Cl^- > HCO_3^- > NO_3^-$, $Mg^{2+} > Ca^{2+} > Na^+ > K^+$ *and* $Fe^{2+} > Zn^{4+} > Cu^{2+} > Mn^{4+}$ *are within approved WHO standard values for drinking water. The hydrochemical facies are Na-(K)-Cl (dominant) and Ca-(Mg)-Cl water types. Irrigation indices (sodium absorption ratio, residual sodium bi-carbonate, permeability index) signified good quality water suitable for agricultural use while magnesium absorption ratio and Kelly's ratio were indicative of moderately suitable irrigation water.*

KEYWORDS: *Ekiti Basement Area. Springs. Irrigation. Colorimetric method. Mineralized.*

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I. INTRODUCTION

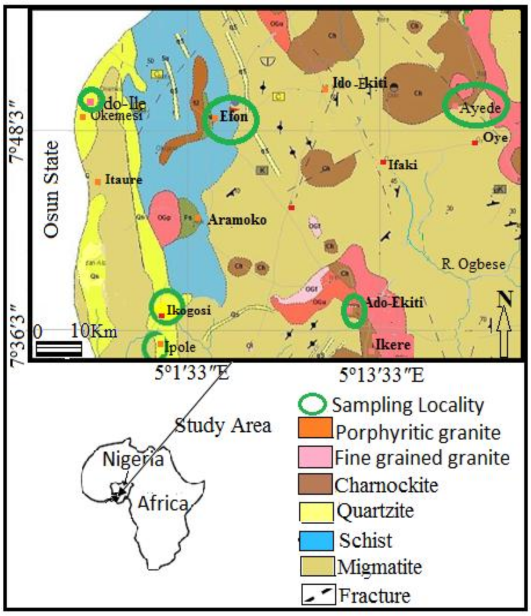
Water is an essential commodity with an unparalleled value after air. Water plays significant roles in the biosphere (in animals and plants kingdoms), atmosphere (air) and lithosphere (rock units) (Aderogba, 2005, Mayer's, 2005). It represents a unique feature in every settlement for drinking, sanitation, washing, fishing, recreation and industrial uses. Water can occur as surface water in lakes, rain and stream as well as groundwater in wells, boreholes and springs. The distribution of world's water indicates that only 2.5% constitutes fresh water, out of this, surface water and groundwater have 0.4% and 30.1% respectively (*http://www.greenfacts.org/en/water-resources/figtableboxes/8.htm*). In 2010, UNICEF, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation indicated that about 85% of the global population (6.74 billion people) had access to piped water supply through house connections or to an improved water source through other means than house, including standpipes, water kiosks, spring supplies and protected wells. However, about 14% (884 million people) did not have access to an improved water source and had to use unprotected wells or springs, canals, lakes or rivers for their water needs. Throughout the history of humanity, water has always sustained life and communities and the quality of available water is essentially an index of the living standard. In Nigeria, the surface water resources available is about 224 trillion Litres per year and that of groundwater is about 50 million trillion Litres per year for a population of about 128 million with domestic consumption need of 6.0 billion Litres per year (Akujieze et al., 2003). In addition, abundant surface water and groundwater exist in southern Nigeria, particularly in the south western region lying within the tropical rainforest zone (Adekunle et al., 2007). In the study area (Ekiti Basement complex Area), water requirements to sustain agriculture that constitute over 80% of the workforce as well as domestic purposes are met from surface water and groundwater.

However, surface water availability is seasonal and most streams and rivers dried off in the dry season leaving irrigation and domestic water supply to become heavily dependent on groundwater systems. In most situations, spring waters specifically serve as alternative source of water for domestic purposes especially during the dry season when most shallow hand dug wells must have dried off. Springs are underground water that have found their way to the surface from within the crust through the loose sand or distorted rocks to flow as streams. Such migration is influenced either by gravity water chemistry or temperature gradient (Davis and De Wiest, 1966). Freshwater from the spring could be directly discharged onto the ground surface, directly into the beds of rivers or streams or into the ocean below sea level. Spring water was associated in the public mind with exceptional quality. As a matter of fact, bottling of spring water has become a blooming business across the world (King, 2008). The importance of springs have gone beyond just being sources of domestic and municipal water supply but also sources for foreign exchange earnings as they serve as places for tourist attraction (Aniah, et al., 2009) and industrial establishment where safe drinking water could be bottled.Water chemistry to a large extent, is influenced by elemental distribution often determine by the lithologic effects, climate, groundwater flow and anthropogenic activities (Berner and Berner, 1981, Gorham, 1961). In addition, the sources of water for any specific purpose are not as important as the suitability of the water for the desired purpose as the exposed springs can be contaminated through anthropogenic activities. With increasing human population, industrialization, urbanization and the consequent increase in demand for water for domestic and industrial uses, the increase in the implication of polluted water on man and the environment have been on the increase and have been severally studied (Asiwaju – Bello and Akande, 2004; Ige et al., 2008). Assessment of springs' waters especially in Ekiti state is therefore necessary as increased knowledge of processes that controls chemical compositions of the springs' waters can improve the understanding of their usability status apart from guide against outbreak of water borne diseases. This research work therefore aimed at assessing the quality and hydrochemical characteristics of selected springs in Ekiti Basement Complex Area, southwestern, Nigeria.

II. LOCATION AND GEOLOGY:

The study area (Ekiti Basement Complex Area) is within the Precambrian-Lower Proterozoic Basement Complex terrain of southwestern Nigeria (Jones and Hockey, 1964, Rahaman, 1976). The area lies within Latitudes 7º 34′ 3″N to 7º 55′ 44″N and Longitudes 4º 51′ 25″E to 5º 22′ 37″E (Fig. 1). The study localities comprising of eleven (11) distinct springs randomly distributed with Olotolo spring in Ado-Ekiti, Omikurudu, Oloriri and Olatomori springs in Ayede-Ekiti and Elegbewa, Eleyiru and Onitokin springs in Ido-Ile-Ekiti. Others include Ikogosi warm spring in Ikogosi-Ekiti, Arinta spring in Ipole-Ekiti and Arioye and Afeni springs in Efon-Alaye-Ekiti. The springs have history of continuous supply of water throughout the year and are therefore targeted for hydrochemical assessment since they are used for domestic purposes especially during dry season when most surface water and shallow wells might have dried off. The Arinta waterfall at Ipole-Ekiti is about 6km southwest of Ikogosi, and could be reached through a secondary road from Ikogosi tourist centre. Ikogosi spring is situated in the ikogosi town of Ekiti west Local Government area of Ekiti State. Ikogosi spring is separated from Arinta spring in Ipole-Iloro by the massive Effon ridge 100m above the sea level. Both Arinta and Ikogosi springs are tourist centres that generate revenue for Ekiti state government.The principal rock units include Precambrian migmatite-gneiss-schist complex constituting over 60% of the sampling localities into which other rocks intruded during the Pan-African orogeny. Among the rocks that intruded into the migmatite-gneiss-schist complex were the charnockite, fine grained granite and porphyritic granite. Late magmatic pegmatitic intrusions were recorded in part of the study area.

Field sampling and analytical methods: Thirty (30) springs' water samples [Olotolo spring (5), Omikurudu spring (3), Oloriri spring (1), Olatomori spring (1), Elegbewa spring (3), Eleyiru spring (2), Onitokin spring (1), Arioye spring (2), Afeni spring (2), Arinta spring (3) and Ikogosi spring (7)] were collected in polyethylene bottles in duplicate with one of the samples acidified with concentrated nitric acid for cation determination while the unacidified samples were for anions analyses. All samples were refridgerated at 4^oC before taken to the Laboratory for analysis. Prior to collection, the bottles were washed with distilled water and subsequently rinsed thoroughly with the sample water. During the sampling exercise, insitu measurement of temperature (^oC), EC (µs/cm) and pH were carried out using Multi-parameter Testr^{Tm} 35 series. Cation concentrations were measured by the Buck Scientific Model 210VGP Atomic Absorption Spectrophotometer (AAS) while the anions were analyzed using colrimetric method. The software SPSS version 17.0 was used for statistical analyses. Graphical plots (Piper and Schoeler diagrams) were employed to unravel the hydrochemical characteristics and evolution of the spring water. US salinity diagram along with some estimated irrigation indices including Sodium Absorption Ratio (SAR), Residual Sodium Bicarbonate (RSBC), Permeability Index (PI), Magnesium Absorption Ratio (MAR) and Kelly Ratio (KR) were estimated to determine the irrigation quality of the springs. The irrigation indices were estimated using the following formulae:



a) $SAR = \dfrac{Na}{\sqrt{\dfrac{Ca + Mg}{2}}}$ (Richards, 1954) (1)

b) $RSBC = HCO3 - Ca$ (Gupta and Gupta, 1987) (2)

c) $PI = \dfrac{(Na + \sqrt{HCO_3}) * 100}{Ca + Mg + Na}$ (Doneen, 1962) (3)

d) $MAR = \dfrac{Mg * 100}{Ca + Mg}$ (Ragunath, 1987) (4)

e) $KR = \dfrac{Na}{Ca + Mg}$ (Kelly's, 1963) (5)

All ionic concentrations are in meq/L.

Fig. 1 Location and geologic map of study area
(After GSN, 2010)

III. RESULTS AND DISCUSSION

Spring waters chemistry: The summary of the result of phsico-chemical parameters of water samples from the 11 selected springs in Ekiti Basement Complex Area is presented in Table 1 while results of the physical and chemical parameters are presented in Tables 2 and 3 respectively. The selected springs waters in Ekiti state have pH range of 5.7 – 11.5 (av. 7.95). Seventeen of the sampled waters (56.67%) have pH values within the approved WHO (2008) standard for drinking water i.e. between 6.5 and 8.5. The pH values for the 17 samples are greater than the neutral pH values of seven (7) reflecting weak alkaline waters. Eight (8) of the water samples representing 26.67% are slightly acidic with pH<7. Rock units have no significant effects on the pH values of the different springs. Ikogosi warm spring and Arinta spring located on quartzite/quartz-schist have alkaline water similar to Olotolo spring on migmatite-gneiss/granitic bedrocks. However, other water samples from springs located variably on psammite, migmatite-gneiss/charnockite and migmatite-gneiss/granites are slightly acidic to alkaline. The slight acidity of few of the water samples might be from contribution of H^+ ions arising from weak carbonic acid (formed by rainwater percolating through organic matter in the soil) interacting with the bedrocks. Natural rainwater interacts with carbon dioxide (CO_2) in the atmosphere, forming carbonic acid ($H_2 CO_3$). Some of the carbonic acid in the rainwater then dissociates producing more hydrogen ion and bicarbonate ion, both of which are dissolved in the rainwater. The two reactions in rainwater are as follows:

$$H_2O + CO_2 \longrightarrow H_2CO_3 \qquad (7)$$

$$H_2CO_3 \longrightarrow HCO_3^- + H^+ \qquad (8)$$

The hydrogen ion produced by the second reaction (equation 8) lowers the pH of rain-water. How far it lowers it from the neutral value of 7 depends on how much carbonic acid is in the water as a result of the first reaction. This action equally triggered water-rock interactions that were responsible for major solute input into the springs. According to the World Health Organization, health effects are most pronounced in pH extremes. Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation. On the opposite end of the scale, pH values below 4 also cause irritation due to the corrosive effects of low pH levels. Cases of extreme pH values are rare in the study area. Generally, the EC is low ranging between 19 and 239µS/cm. The TDS values are equally low with mean value of 79.73mg/L. The low values of EC are mainly attributed to geochemical processes prevailing in this region. The springs are being recharged from recent precipitation that has low water-rock interactions and low residence time within the aquiferous zones. However, both EC and TDS vary widely among the samples which are reflected in the form of high standard deviation (59.84) for these ions (Table 1). Total hardness results in all the water samples range from 2.14 – 83.27mg/L with mean value of 19.64mg/L.

Ninety percent (90%) of the sampled springs' waters have TH below 70 mg/L and could be described as soft water while the remaining 10% (AFN2, OLO4 and OLO5) have TH values greater than 70 mg/L but less than 120 mg/L indicating moderately hard water (Environment Canada, 1977). Water supplies with hardness greater than 200 mg/L are considered poor while those in excess of 500 mg/L are unacceptable for most domestic purposes (WHO, 1993). Generally all values of cations are low and within approved standard values for drinking water (WHO, 2008). Following the same trend, the values of all anions are low. The pie charts of the median values of major ions present in the springs' waters of the study area as reflected in Fig. 2 shows that Na^++ K^+ and Cl^- are dominant cations and anion, respectively. Fig. 2 further illustrates that the median values of Cl^- exceeded 50% of total anions in spring waters of the study area. The trend of ions in the spring waters is in the following order: $Na^+ + K^+ > Ca^{2+} > Mg^{2+}$ and $Cl^- > HCO_3^- > NO_3^-$

Hydrochemical evaluation: Cross-plots along X-Y coordinate as presented in Fig.3 are employed in order to have a better understanding of the evolution of ionic concentrations of the springs' waters in the study area. Fig.3 indicates that water samples from the 11 selected springs plot randomly in the X-Y cross plots. Fig.3a shows the dominance of alkali metals (Na^++K^+) in the springs' water samples which is further exemplified in Fig.3b where alkali metals have 67% dominance compared to earth alkali metals (Ca^{2+}+Mg^{2+}) with 23%. In Fig.3a (Na^+ + K^+ vs total cations), the chemical data of the springs' waters fall below the equiline (thick line) and above the 2(Na^+ + K^+) vs total cations line indicating that the supply of cations via silicate weathering and/or soil salts is more significant (Stallard and Edmond, 1983), whereas the fact that there is no positive correlation between sodium and chloride ions (Fig.3c) reflects a different source for these ions (Datta and Tyagi, 1996). Unlike many ions, nitrate is not derived from rocks; rather it is often associated with faecal pollution (Adeyemi et al., 2003). A cross plot of nitrate vs chloride (Fig.3d) indicates low positive correlation. Schlesinger (2004) estimated that more than one hundred and forty (140) trillion kilograms of chloride are annually cycled through various reservoirs on Earth, almost all of it due to human activities.

Thus, it can be inferred that the chloride ions in the springs' waters of the study area are sparsely from different sources; dissolved rocks and soil, faecal pollutants and mostly from waste water from municipalities, water softening and agricultural runoff. The observed excess of sodium over potassium ions in the water samples is because of the greater resistance of K^+ to chemical weathering and its adsorption on clay minerals (Subba Rao 2008). The geochemical process further indicates that calcium undergoes reaction more with bicarbonate than sodium (Fig. 3e) producing Ca-(Mg)-HCO_3 water while Na reacts more with chloride and sulphate to produce Na-(K)-Cl-(SO_4) water type (Fig.3f). The excess chloride ions are left to take on the available calcium and magnesium that have not reacted with bi-carbonate resulting in Ca-(Mg)-Cl-(SO_4) water. Plot of Ca^{2+}+Mg^{2+} vs. total cations shows that most water samples from the springs are below the theorectical line 1:1 (Fig. 3g), indicating an increasing contribution of alkalis to the major ions arisen from silicates weathering (Subba Rao, 2008). Chadha plots (Fig. 4) further revealed cations exchange process and dilution/Mixing processes as responsible for groundwater evolution in the study area. Aghazadeh and Mogaddam (2010) described chloro-alkaline indices-1 (CA-1) to indicate the changes in chemical composition of groundwater during its travel in the subsurface. As regards ion exchange of Na and K from water with Ca and Mg from the soil, the indices are positive while if the exchange is reverse, then the indices are negative. The ion exchange between the springs' waters and their host environment during residence or travel time in the study area is verified by employing the chloro-alkaline indices; CAI-1 and CAI-2 (Schoeller 1967). The indices are defined as follows;

CAI-1 = $[Cl - (Na + K)]/Cl$ (9)

CAI-2 = $[Cl - (Na + K)]/ (SO_4 + HCO_3 + CO_3 + NO_3)$ (10)

The statistics of CA1 and 2 of the study area indicates that 100% of the springs' water samples have positive values with CA-1, CA-2 ranging from 0.59 – 1.00 and 2.60 – 12.48 respectively. The chloro-alkaline positive values indicate that the springs' water of Ekiti Basement Area has suffered ion exchange between alkali and alkaline earth metals.

Classification of ionic composition of the 'springs' water: The relative ionic composition of water samples collected from springs in the study area is plotted on a Piper Trilinear diagram (Fig. 5), (Piper, 1944). The diagram provides a convenient method to classify and compare water types based on the ionic composition of different water samples (Hem, 1985) and reveals similarities and differences among water samples because those with similar qualities will tend to plot together as groups (Todd, 2001). Cation and anion concentrations for each spring water sample in meq/L are plotted as percentages of their respective totals in two triangles (fig. 5). The cation and anion relative percentages in each triangle are then projected into a quadrilateral polygon that describes the water type or hydrochemical facies. Waters from the springs are classified as Na-(K)-Cl-(SO4) water (dominant) and Ca-Mg-Cl-(SO_4) water. This classification is supported by Schoeler diagram (Fig. 6) that indicates sodium and chloride as dominant cation and anion respectively.

Springs' water irrigation quality assessment : Irrigation waters whether derived from springs, diverted from streams or pumped from wells, contain appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility. Different irrigation quality parameters (SAR, RSC, MAR, PI and KR) were calculated for the quality evaluation of the selected springs' water for irrigation purposes. Results from the estimations are as presented in Table 4. SAR, RSBC, MAR, PI and KR range from 0.06 – 5.02, -0.68 – 1.14, 1.64 – 38.81, 23.56 – 107.59 and 0.32 – 8.54 respectively. Plants are detrimentally affected, both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others. Soils with an accumulation of exchangeable sodium are often characterized by poor tilth and low permeability making them unfavorable for plant growth. SAR is an easily measured property that gives information on the comparative concentrations of Na^+, Ca^{2+}, and Mg^{2+} in the water samples of the springs. The SAR takes into consideration the fact that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions. When the SAR rises above 12 to 15, serious physical soil problems arise and plants have difficulty absorbing water (Munshower, 1994, Brady, 2002). In the study area, all values of SAR for the different springs' water samples are less than 10 indicating suitability for irrigation purpose. Water quality criteria can be used as guidelines by farmers for selecting appropriate management practice to overcome potential salinity hazard, if the quality of available water would pose any problem for irrigation to maintain existing soil productivity with the benefit of high crop yield under irrigation (Ramesh and Elango, 2010).

Sodium Hazard and Salinity Hazard : EC and Na^+ are very important in classifying irrigation water. To evaluate the effects of Na^+ and EC on the springs' water, chemical data are plotted on US Salinity diagram (Richard, 1954). The diagram (Fig. 6) shows that all water samples have low alkalinity hazard with moderate salinity hazard. It is inferred that the springs' water is suitable for irrigation.

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Residual Sodium Bi-carbonate : RSBC has been calculated to determine the hazardous effect of CO_3^{2-} and HCO_3^- on the quality of water for agricultural purpose (Eaton, 1950). The calculated RSC (-0.68 to 1.14) in the water samples of the study area are less than 1.2. USEPA (1999), indicated that RSBC<1.25 are safe for irrigation while RSBC>2.5 is considered unsuitable revealing that the springs' water is safe for irrigation purpose. The negative values of RSBC in some of the water samples are indication that Na^+ buildup is unlikely due to sufficient Ca^{2+} and Mg^{2+} that are available in excess of what can be precipitated as CO_3^{2-} and HCO_3^-.

Table 1 Summary of physico-chemical parameters of selected spring waters in Ekiti state

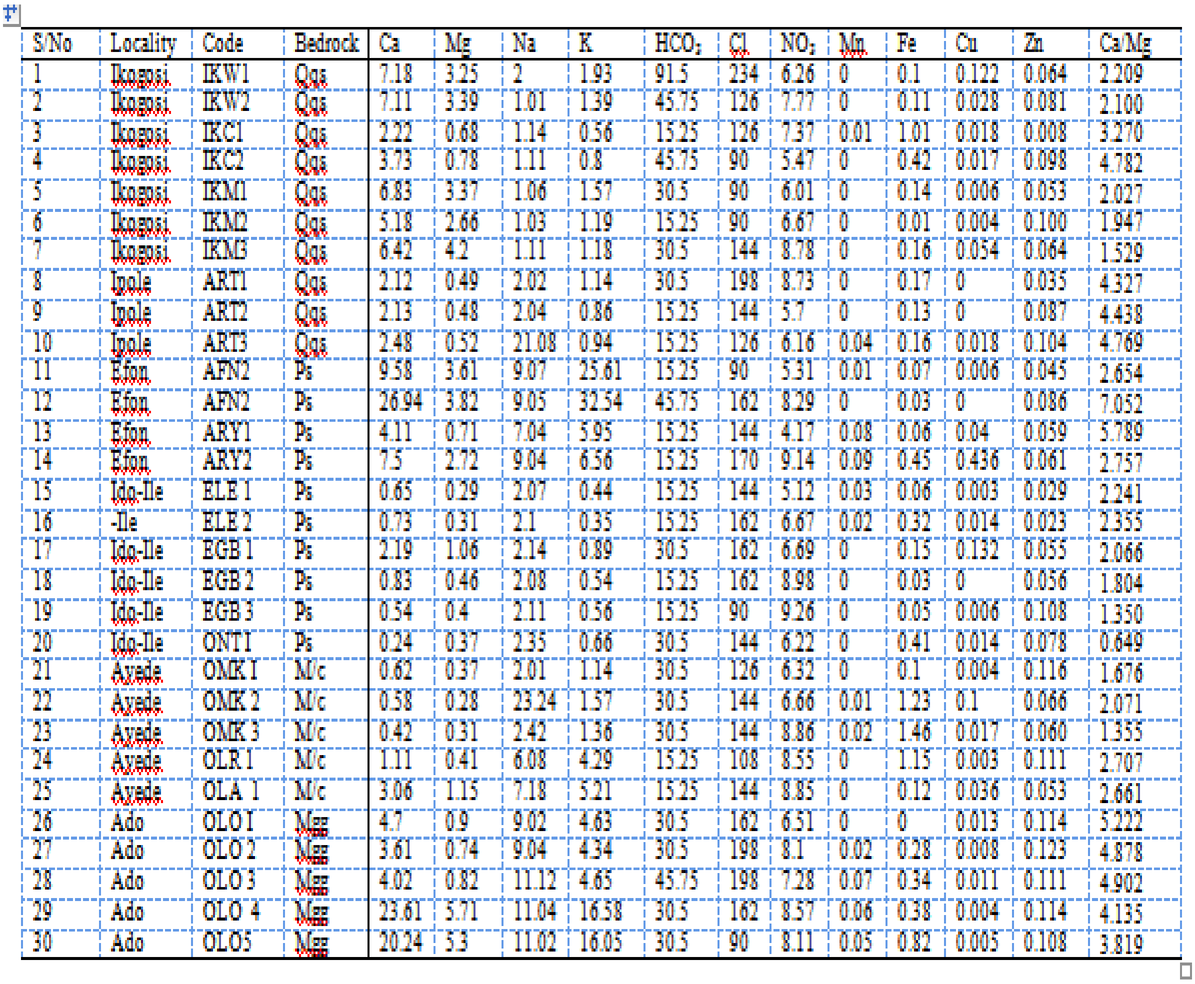
Parameters	Min	Max.	Mean	Median	Stdev
Temp (ºC)	19.70	34.50	25.30	24.9	4.19
pH	5.70	11.50	7.95	7.7	1.41
EC (μs/cm)	19.00	239.00	79.73	76.5	59.84
TDS (mg/L)	14.25	179.30	59.83	57.66	44.88
TH (mg/L)	2.14	83.27	19.64	12.28	22.97
Ca (mg/L)	0.24	26.94	5.36	3.34	6.74
Mg (mg/L)	0.18	33.94	2.65	0.76	6.13
Na (mg/L)	1.01	23.24	5.76	2.25	5.75
K (mg/L)	0.35	32.54	4.85	1.38	7.77
HCO_3 (mg/L)	15.25	91.50	27.96	30.50	16.06
NO_3 (mg/L)	4.17	9.26	7.22	144.00	1.41
Mn (mg/L)	0.00	0.09	0.02	6.99	0.03
Fe (mg/L)	0.00	1.46	0.33	0.00	0.40
Cl (mg/L)	90.00	234.00	142.47	0.16	36.89
Cu (mg/L)	0.00	0.44	0.04	0.01	0.08
Zn (mg/L)	0.01	0.12	0.08	0.07	0.03
CAI-1	0.59	1.00	0.90	0.97	0.11
CAI-2	2.60	12.48	7.08	6.63	2.82

Table 2 Chemical parameters (mg/L) of spring waters in Ekiti basement terrain

S/No	Locality	Code	Bedrock	Temp (ºC)	PH	EC (µs/cm)	TDS (mg/L)	TH (Meq/L)
1	Ikogosi	IKW1	Qqs	34.50	7.40	88.00	66.00	31.49
2	Ikogosi	IKW2	Qqs	34.40	8.30	89.00	66.75	15.92
3	Ikogosi	IKC1	Qqs	22.10	8.70	19.00	14.25	6.30
4	Ikogosi	IKC2	Qqs	22.40	8.60	45.00	33.75	12.58
5	Ikogosi	IKM1	Qqs	32.90	8.40	88.00	66.00	31.12
6	Ikogosi	IKM2	Qqs	31.90	8.80	85.00	63.75	24.03
7	Ikogosi	IKM3	Qqs	32.00	9.00	86.00	64.50	33.55
8	Ipole	ART1	Qqs	19.70	8.00	27.00	20.50	7.34
9	Ipole	ART2	Qqs	19.70	7.80	31.00	23.25	7.33
10	Ipole	ART3	Qqs	19.70	7.60	30.00	22.50	8.37
11	Efon	AFN1	Ps	26.10	5.80	97.00	72.25	38.99
12	Efon	AFN2	Ps	24.40	6.20	223.00	167.25	83.27
13	Efon	ARY1	Ps	25.50	5.70	118.00	88.50	13.23
14	Efon	ARY2	Ps	26.30	6.30	137.00	102.75	30.08
15	Ido-Ile	ELE 1	Ps	21.50	7.60	21.00	15.75	2.83
16	Ido-Ile	ELE 2	Ps	21.90	6.90	25.00	18.75	3.12
17	Ido-Ile	EGB 1	Ps	21.00	9.20	49.00	36.75	9.89
18	Ido-Ile	EGB 2	Ps	23.30	6.50	35.00	26.25	3.12
19	Ido-Ile	EGB 3	Ps	29.00	9.20	29.00	21.75	3.02
20	Ido-Ile	ONT I	Ps	22.40	7.50	21.00	15.75	2.14
21	Ayede	OMK I	M/c	25.50	7.10	30.00	22.50	3.09
22	Ayede	OMK 2	M/c	25.30	6.70	30.00	22.50	2.62
23	Ayede	OMK 3	M/c	25.50	7.10	30.00	22.50	2.34
24	Ayede	OLR 1	M/c	23.70	7.10	68.00	51.56	4.48
25	Ayede	OLA 1	M/c	25.80	6.60	106.00	79.50	12.44
26	Ado	OLO I	Mgg	24.80	11.50	119.00	89.81	15.50
27	Ado	OLO 2	Mgg	25.50	10.60	117.00	87.75	12.11
28	Ado	OLO 3	Mgg	25.00	9.70	122.00	91.50	13.47
29	Ado	OLO 4	Mgg	23.90	9.10	239.00	179.25	82.82
30	Ado	OLO5	Mgg	23.20	9.60	188.00	141.00	72.68

Qqs: Quartzite/quartz-schist, M/c: Migmatites/charnockite, Mgg: Migmatite-gneiss/granite, Ps: Psammite IKW1-IKW2; Ikogosi warm spring, IKC1-IKC2; Ikogosi cold spring, IKM1-IKM3; Ikogosi mixed spring, ART1-ART3; Arinta spring; AFN1-AFN2; Afeni spring; ARY1-ARY2; Arioye spring; ELE1-ELE2; Eleyiru; EGB1-EGB3; Elegbewa; ONT1; Onitokin spring; OMK1-OMK3; Omikurudu spring; OLR1; Olorori spring, OLA1; Olatomori spring and OLO1-OLO5; Olotolo spring.

Table 3 Chemical parameters (mg/L) of spring waters in Ekiti basement terrain



S/No	Locality	Code	Bedrock	Ca	Mg	Na	K	HCO_3	Cl	NO_3	Mn	Fe	Cu	Zn	Ca/Mg
1	Ikogosi	IKW1	Qqs	7.18	3.25	2	1.93	91.5	234	6.26	0	0.1	0.122	0.064	2.209
2	Ikogosi	IKW2	Qqs	7.11	3.39	1.01	1.39	45.75	126	7.77	0	0.11	0.028	0.081	2.100
3	Ikogosi	IKC1	Qqs	2.22	0.68	1.14	0.56	15.25	126	7.37	0.01	1.01	0.018	0.008	3.270
4	Ikogosi	IKC2	Qqs	3.73	0.78	1.11	0.8	45.75	90	5.47	0	0.42	0.017	0.098	4.782
5	Ikogosi	IKM1	Qqs	6.83	3.37	1.06	1.57	30.5	90	6.01	0	0.14	0.006	0.053	2.027
6	Ikogosi	IKM2	Qqs	5.18	2.66	1.03	1.19	15.25	90	6.67	0	0.01	0.004	0.100	1.947
7	Ikogosi	IKM3	Qqs	6.42	4.2	1.11	1.18	30.5	144	8.78	0	0.16	0.054	0.064	1.529
8	Ipole	ART1	Qqs	2.12	0.49	2.02	1.14	30.5	198	8.73	0	0.17	0	0.035	4.327
9	Ipole	ART2	Qqs	2.13	0.48	2.04	0.86	15.25	144	5.7	0	0.13	0	0.087	4.438
10	Ipole	ART3	Qqs	2.48	0.52	21.08	0.94	15.25	126	6.16	0.04	0.16	0.018	0.104	4.769
11	Efon	AFN2	Ps	9.58	3.61	9.07	25.61	15.25	90	5.31	0.01	0.07	0.006	0.045	2.654
12	Efon	AFN2	Ps	26.94	3.82	9.05	32.54	45.75	162	8.29	0	0.03	0	0.086	7.052
13	Efon	ARY1	Ps	4.11	0.71	7.04	5.95	15.25	144	4.17	0.08	0.06	0.04	0.059	5.789
14	Efon	ARY2	Ps	7.5	2.72	9.04	6.56	15.25	170	9.14	0.09	0.45	0.436	0.061	2.757
15	Ido-Ile	ELE 1	Ps	0.65	0.29	2.07	0.44	15.25	144	5.12	0.03	0.06	0.003	0.029	2.241
16	-Ile	ELE 2	Ps	0.73	0.31	2.1	0.35	15.25	162	6.67	0.02	0.32	0.014	0.023	2.355
17	Ido-Ile	EGB 1	Ps	2.19	1.06	2.14	0.89	30.5	162	6.69	0	0.15	0.132	0.055	2.066
18	Ido-Ile	EGB 2	Ps	0.83	0.46	2.08	0.54	15.25	162	8.98	0	0.03	0	0.056	1.804
19	Ido-Ile	EGB 3	Ps	0.54	0.4	2.11	0.56	15.25	90	9.26	0	0.05	0.006	0.108	1.350
20	Ido-Ile	ONTI	Ps	0.24	0.37	2.35	0.66	30.5	144	6.22	0	0.41	0.014	0.078	0.649
21	Ayede	OMK I	M/c	0.62	0.37	2.01	1.14	30.5	126	6.32	0	0.1	0.004	0.116	1.676
22	Ayede	OMK 2	M/c	0.58	0.28	23.24	1.57	30.5	144	6.66	0.01	1.23	0.1	0.066	2.071
23	Ayede	OMK 3	M/c	0.42	0.31	2.42	1.36	30.5	144	8.86	0.02	1.46	0.017	0.060	1.355
24	Ayede	OLR 1	M/c	1.11	0.41	6.08	4.29	15.25	108	8.55	0	1.15	0.003	0.111	2.707
25	Ayede	OLA 1	M/c	3.06	1.15	7.18	5.21	15.25	144	8.85	0	0.12	0.036	0.053	2.661
26	Ado	OLO I	Mgg	4.7	0.9	9.02	4.63	30.5	162	6.51	0	0	0.013	0.114	5.222
27	Ado	OLO 2	Mgg	3.61	0.74	9.04	4.34	30.5	198	8.1	0.02	0.28	0.008	0.123	4.878
28	Ado	OLO 3	Mgg	4.02	0.82	11.12	4.65	45.75	198	7.28	0.07	0.34	0.011	0.111	4.902
29	Ado	OLO 4	Mgg	23.61	5.71	11.04	16.58	30.5	162	8.57	0.06	0.38	0.004	0.114	4.135
30	Ado	OLO5	Mgg	20.24	5.3	11.02	16.05	30.5	90	8.11	0.05	0.82	0.005	0.108	3.819

Qqs: Quartzite/quartz-schist, M/c: Migmatites/charnockite, Mgg: Migmatite-gneiss/granite, Ps: Psammite

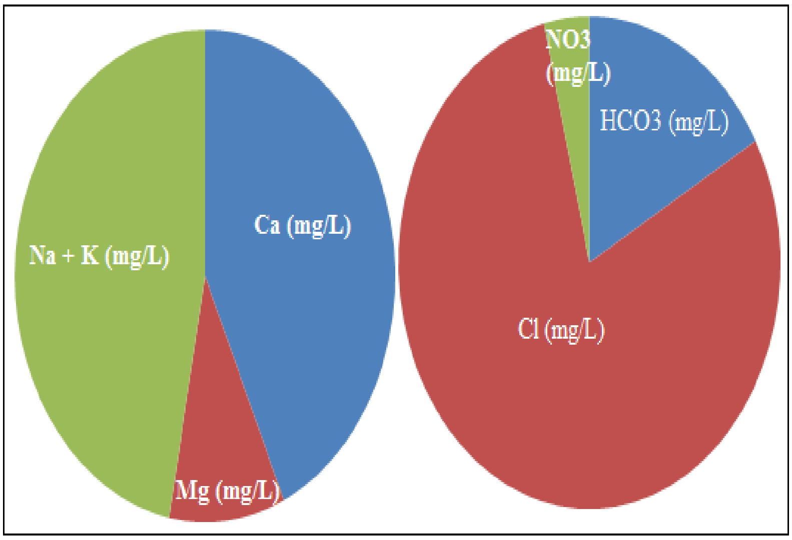


Fig 2 Pie diagram of ionic trend in the springs waters

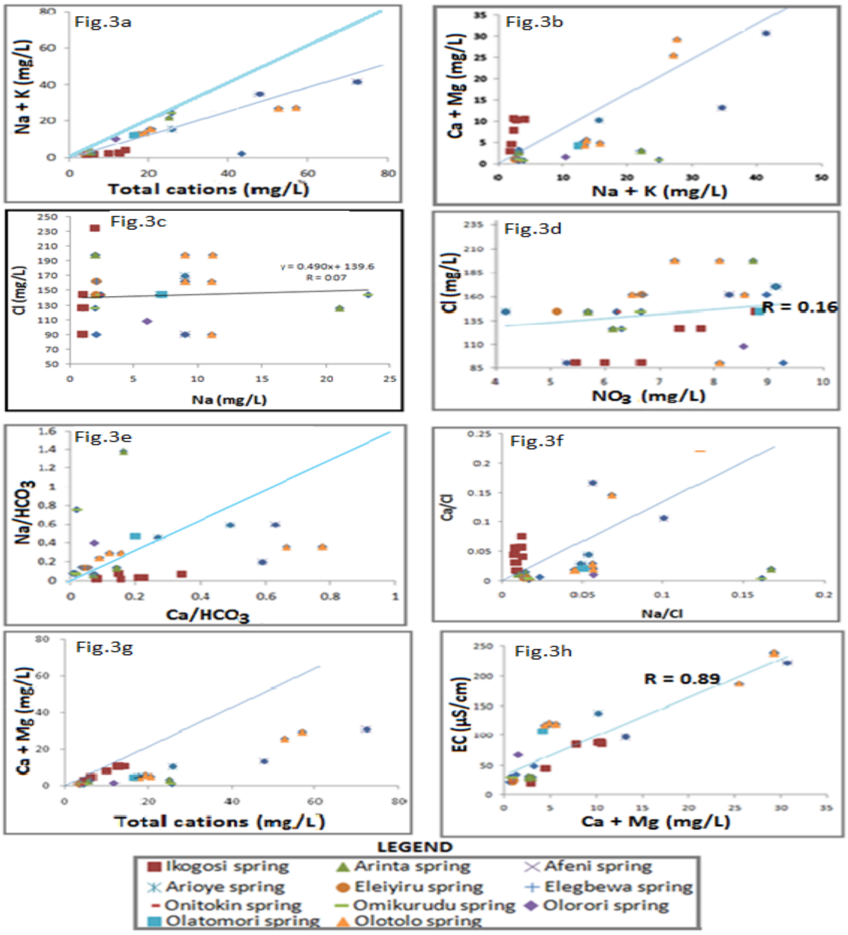


Fig. 3 Cross Plots of some ions of selected spring waters in Ekiti state

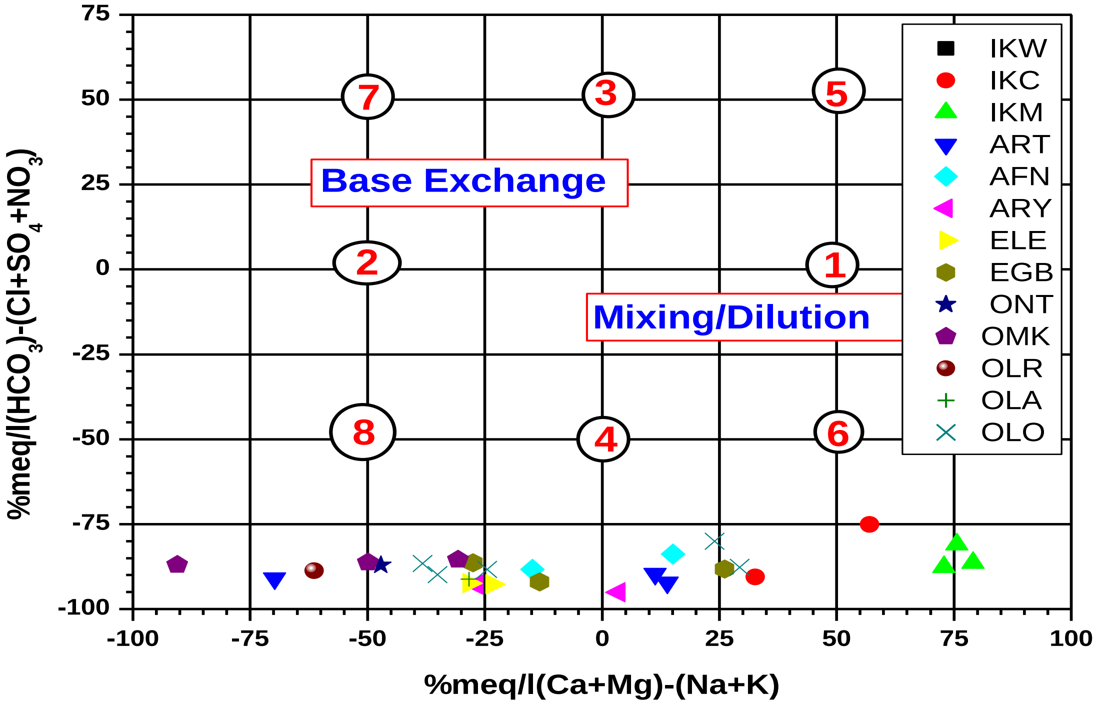


Fig. 4 Chadha (1999) Plot for springs' waters of the study area

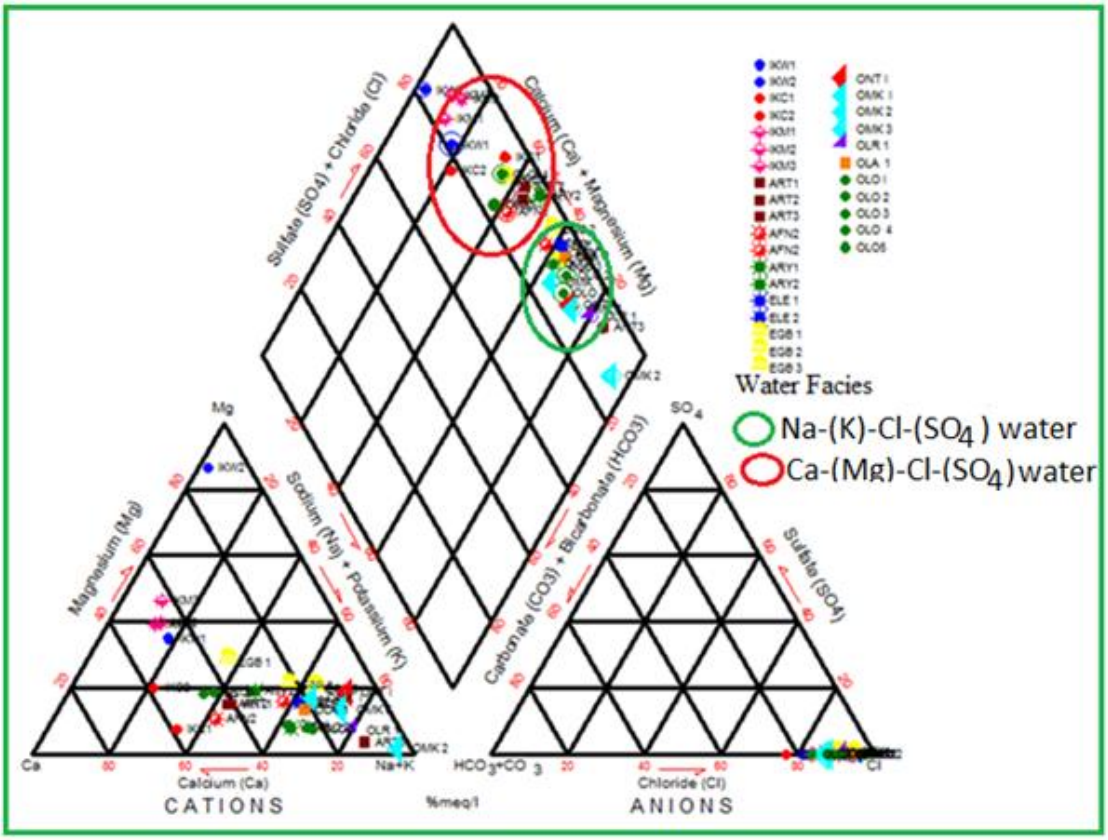


Fig. 5 Piper diagram

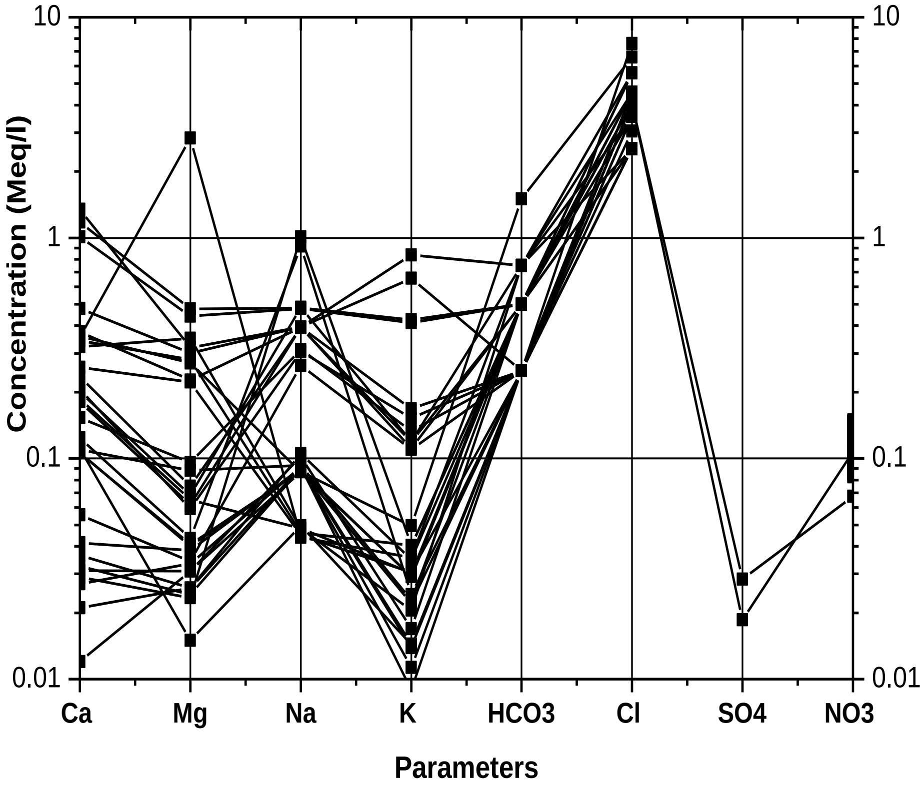


Fig. 6 Schoeler diagram

Magnesium Absorption Ratio (MAR) : The magnesium hazard as redefined by Ragunath (1987) is employed in this study. The MAR >50 is considered harmful and unsuitable for irrigation purpose. Calculated MAR for the springs' water in Ekiti Basement Terrain range from 23.56 – 107 .59 with average value of 58.82. Twelve (40%) out of the 30 springs' water samples have MAR>50 indicating that the spring water is marginally suitable for irrigation use.

Table 4 Summary of irrigation quality parameters

Parameters	Min	Max	Mean	Stdev
SAR	0.06	5.02	0.64	0.94
RSBC	-0.68	1.14	0.19	0.37
PI	1.64	38.81	8.84	8.74
MAR	23.56	107.59	58.82	23.91
KR	0.32	8.54	2.08	2.07

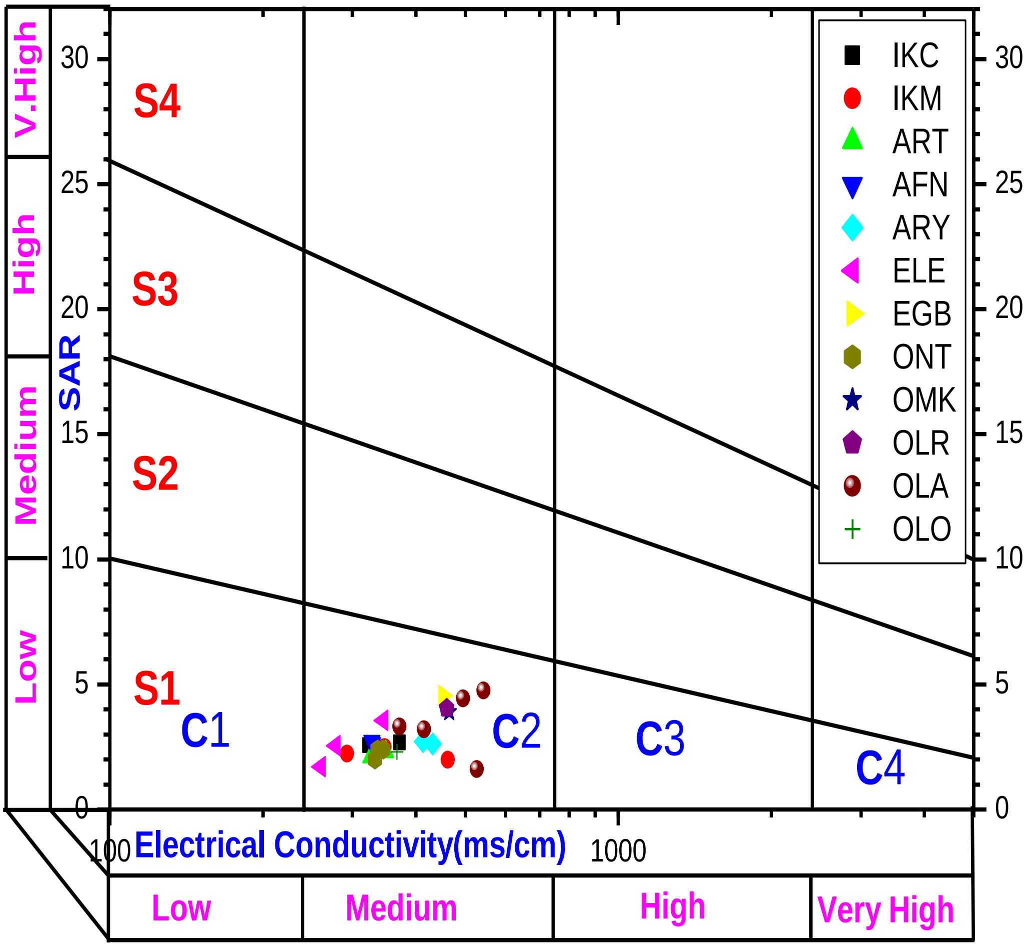


Fig. 7 Classification of springs' water based on US salinity diagram

Permeability Index (PI): The soil permeability is affected by long term use of irrigation water. A criterion for assessing the suitability of water for irrigation based on PI have 3 classes as class I, Class II and Class III orders. Class I and Class II water was categorized as good for irrigation with 75% or more maximum permeability, Class III water was unsuitable with 25% of maximum permeability (Doneen, 1964; Raghunath, 1987, Nagaraju et al., 2006). In the present study the PI range between 1.64 and 67.57% with average value of 13 which comes under class-1 of Doneen's chart indicating that the springs' water quality was suitable for irrigation.

Kelly's ratio (KR) : Based on Kelly's ratios (Kelly, 1963) ground water was classified for irrigation with KR> 1 indicating an excess level of sodium in water; therefore water with Kelly's ratio of less than 1 was suitable for irrigation. In this study , 56% of the springs' water samples have KR>1 while the remaining 44% have KR<1 indicating that excess Na occurs in some of the springs water and will be good as irrigation water for the salt tolerant plants.

IV. CONCLUSION

The present study has been carried out to evaluate the quality status of Ekiti Basement Terrain springs' water with respect to domestic and irrigation purposes. Geochemistry of the springs' water displays $Na^+ + K^+ > Ca^{2+} > Mg^{2+}$ and $Cl^- > HCO_3^- > NO_{3-}$ trend with $Na^+ + K^+$ and Cl^- as dominant cations and anion, respectively. All measured physico-chemical parameters are within WHO approved standards for drinking water except in few locations where pH exceeded the standard values. The hydrochemical trend signifies low mineralized water with low water-rock interactions and residence time. Major water facies are Na-(K)-Cl-(SO4) water (dominant) and Ca-Mg-Cl-(SO_4) water which is a reflection of geology and climate of the study area. The positive chloro-alkaline indices revealed that the springs' water has undergone ion exchange between Na + K ions in the water with Ca and Mg of soil during the residence time of the water. The irrigation indices signified good quality water for irrigation use except in few locations where values of MAR and KR are indicative of moderately suitable water for irrigation.

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