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Geochemistry and Quality Characterization of Effon Psammite Ridge Spring Water, Southwestern Nigeria

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Abstract

This study evaluates the geochemistry and quality characterization in the Effon Psammite Spring, Southwestern Nigeria. Fifteen (15) water samples were collected from the study area at regular intervals and samples were analyzed in order to determine their quality characteristics. Except for pH values that is mildly acidic to slightly alkaline in some locations, the physico-chemical properties are below the WHO recommended standards for drinking water. The low values of the conductivity are mainly attributed to geochemical processes prevailing in the area. The mean concentration of the cations follows the order: Na^+ >Ca^{2+} >K^+ >Mg^{2+} while for anions, HCO_3^- >Cl^- > PO_3^- >SO_4^{2-} >NO_3^-. The water is mildly acidic to alkaline due to dissociation of bicarbonate with the following water types: Na-SO_4-Cl, Na-HCO_3, Ca-Na-SO_4 and Ca-Mg-HCO_3-SO_4 which are a reflection of geology and climate of the area. The mildly acidic to alkaline indices revealed that the spring 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 springs are being recharged from recent precipitation that has low water-rock interactions and low residence time within the aquiferous zones. The hydrochemical trend signifies low mineralized water with low water-rock interactions and residence time. Based on these water types and the presence of Na^+, the concentrations of cations are geogenic in origin and might have come from the interaction of water and the rock or introduced from weathering of rocks into the spring water. It is recommended that effective development of springs should involve thorough examination of their seasonal discharges, including during the summer. In case water supply exceeds use, the surplus waters may be stored for future use in horticulture and to irrigate crop land. Moreso since springs are yet to receive substantial attention, utmost care must be taken to protect the Effon Psammite spring from contamination.

Keywords: Water quality; Spring water; Geochemistry; Effon; Nigeria

Introduction

Springs are natural outlets through which groundwater emerges at the ground surface as concentrated discharge from an aquifer are one of the most conspicuous forms of natural return of groundwater to the surface [1]. Conditions necessary to produce springs are many and are related to different combinations of geologic, hydrologic, hydraulic, pedological, climatic and even biologic controls [2]. Springs while flowing downhill from their origins, have formed their own narrow riparian zones on either side of their flow-paths. These riparian zones usually have heavy vegetation growth. Undoubtedly, these plant growths and the seeping spring waters augment the groundwater recharge of the blower aquifers to support the life of the existing springs issuing from these aquifers. 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. Springs are used both for drinking and irrigation purposes by the local inhabitants both at higher elevations and in foothill zones (Figure 1). Spring water was associated in the public mind with exceptional quality and even considered holy in some places. Bottling of spring water has become a blooming business across the world [3]. Apart from tapping springs for drinking/irrigation purposes, they also sustain thousands of other life forms vital to a balanced ecosystem [1]. 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 and industrial establishment where safe drinking water could be bottled [4]. Water chemistry to a large extent, is influenced by elemental distribution often determined by the lithologic effects, climate, groundwater flow and anthropogenic activities [5,6].

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 [7,8]. Assessment of Effon Psammite spring water is therefore necessary as increased knowledge of processes that controls chemical compositions of the spring water can improve the understanding of its usability status apart from guide against outbreak of water borne diseases. This study is therefore aimed at evaluating the quality characteristics as well as examining the possible use of Effon Psammite ridge spring as a potable source of water (Figure 2).

The Study Area, Geology/Hydrogeology

The study area (Ekiti Basement Complex Area) is within the Precambrian-Lower Proterozoic Basement Complex terrain of southwestern Nigeria [9,10]. It is located on coordinates: Latitudes $7^0$38.678'N and $7^0$49.914'N, Longitudes $4^0$54.658'E and $4^0$57.478'E. Highest elevation is about 523 m above mean sea level. Effon Psammite is an extensive quartzite ridge that cut across Ido, Ajinare, Ita-Ido,

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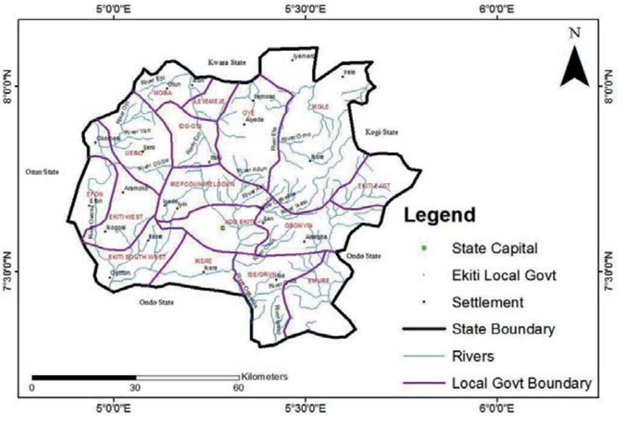

Figure 1: Map of Ekiti State showing the study area-Effon.

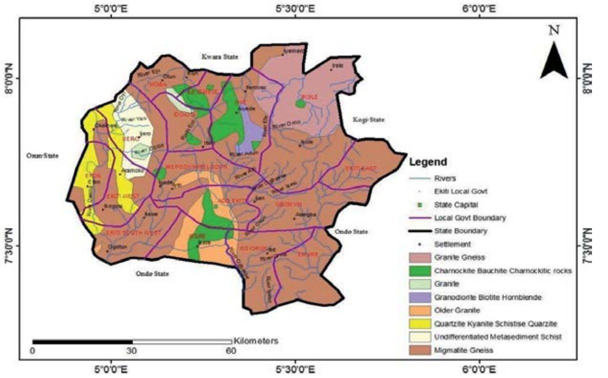

Figure 2: Geologic Map of Ekiti-State, Nigeria.

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The principal rock units in the area 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. All the rocks which have previously been described as Younger metasediments belong in this group e.g., Effon Psammite Formation [9]. The Effon Psammite Formation is a belt of quartzites, quartze schists and granulities which occurs largely east of Ilesha and runs for nearly 180 km in general NNE-SSW direction. The topography of the area is the undulating type, dotted with different outcrops in several places. Most of the rocks in the area are well exposed and are as high as 250 m above sea level and there is prevalence of erosion gullies along hill slopes and valleys.

The drainage system over the area consisting of the basement rocks are usually marked with the proliferation of many smaller river channels. The channels of these smaller streams are dry for many months especially from November to May. There is a major river in the study area called River Oyi and Owawa in Aiyegunle village. The drainage pattern in the south-eastern part of the area where topography is dominated by series of ridges is the trellis type which suggests that the drainage here is structurally controlled whereas, the drainage pattern in other parts of the study area is dendritic, due to homogeneity of the rocks and absence of structures. The Effon Psammite is a NNE-SSW trending ridge highly foliated, jointed, schistose ridge often showing interesting sedimentary structures. The intense deformation structures of these rocks permit adequate aquifer properties needed to generate the springs. Consequently, the quartzite belt stretching NNE-SSW is considered as good aquifer. The surrounding schistose units occur as low yielding aquicludes. Ekiti State has so many springs, amongst which are: 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.

Methods of Study

Fifteen (15) water samples were collected in thoroughly cleaned polyethylene bottles of 1.5 liter capacity. Prior to collection, the bottles were washed with distilled water and subsequently rinsed thoroughly with the sample water. The samples were collected up to top without leaving any space so as to prevent premature release of dissolved gases during the transit period. The samples were preserved with few drops of Nitric acid (HNO_3). After sampling, the lids of the containers were immediately replaced to minimize contamination and escape of gases. The samples were then stored in a cooler and transported to the laboratory for analysis. All analysis was carried out at a standardized laboratory using International regulatory methods. The evaluation of water quality was in accordance with regulatory standard. The approach ensures that the samples collected were tested in accordance with agreed requirements using competent personnel as well as appropriate equipment and materials.

Field Parameters such as pH, Electrical conductivity and temperature were determined on the field due to their unstable nature. These were carried out using Multi-parameter TestrTm 35 series. Cation concentrations were measured by the Buck Scientific Model 210 VGP 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.

Results and Discussion

Except for pH values that is mildly acidic in some locations, all the cations, anions and electrical conductivity are below the WHO (2004) recommended standards for drinking water. The water is slightly acidic to slightly alkaline and could be classified as fresh water [11,12]. These characteristics make the water suitable for both domestic and industrial usage.

The cations range as follows: Ca^{2+} (1.6 – 16.0), Mg^{2+} (0- 7.53), Na^+ (5.58 – 13.32), K^+ (0.19-20.9), while the anions are as follows: HCO_3^- (10.0-79.0), Cl^- (5.0 – 24.0), PO_3^- (3.7 – 14.95), SO_4^{2-} (4.0 – 9.2), NO_3^- (0.12 – 9.27) (Table 1). The mean concentration of the cations is in the order $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ while for anions, $HCO_3^- > Cl^- > PO_3^- > SO_4^{2-} > NO_3^-$. 47% of the water are alkali water predominantly SO_4^{2-} - Cl^-, 20% are alkali water predominantly HCO_3^-, 27% are earth-alkaline water predominantly SO_4^{2-} while 7% are earth alkaline water predominantly HCO_3^-, and SO_4^{2-}. Table 2 is the descriptive statistical summary of the analytical data.

The water is mildly acidic to alkaline due to dissociation of bicarbonate and the following water types: Na-SO_4-Cl, Na-HCO_3, Ca-Na-SO_4 and Ca-Mg-HCO_3-SO_4 which is a reflection of geology and

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S/N	Sample ID	Temp °C	pH	Conduct µs/cm	Suspen Solid	Total Hard	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	PO_3^{-}	SO_4^{-}	NO_3^{-}	HCO_3^{-}
					mg/l										
1	EPS 1	24.4	4.6	74.0	91.0	62.0	12.4	7.53	7.92	0.76	18.0	5.15	8.46	bdl	40.0
2	EPS 2	25.0	6.5	41.0	82.0	46.0	6.8	7.05	6.3	1.52	14.0	10.05	7.21	0.86	30.0
3	EPS 3	24.4	4.3	36.0	84.0	30.0	10.8	0.73	7.02	0.57	12.0	4.4	7.46	bdl	25.0
4	EPS 4	24.1	5.3	24.0	90.0	10.0	4.4	0	6.48	1.33	13.0	12.25	8.21	bdl	25.0
5	EPS 5	24.7	6.0	42.0	98.0	19.0	4.4	1.74	6.66	2.47	22.0	14.7	7.21	bdl	20.0
6	EPS 6	24.7	7.6	43.0	88.0	17.0	3.6	1.78	7.38	1.71	24.0	5.15	6.72	0.23	25.0
7	EPS 7	24.5	7.7	42.0	90.0	6.0	1.6	0.49	9.72	2.66	19.0	12.25	7.46	bdl	15.0
8	EPS 8	23.8	5.7	90.0	94.0	59.0	16	4.62	8.1	2.47	11.0	5.4	6.22	bdl	79.0
9	EPS 9	25.4	6.6	50.0	120.0	11.0	4.4	BDL	9.18	7.22	12.0	14.95	8.93	0.12	20.0
10	EPS 10	24.2	7.0	34.0	116.0	25.0	6.4	2.19	5.58	1.14	10.0	4.9	7.46	bdl	20.0
11	EPS 11	24.2	5.0	23..0	112.0	26.0	6.0	2.67	5.76	0.57	15.0	9.3	9.2	0.58	20.0
12	EPS 12	24.6	6.9	125.0	119.0	40.0	8.4	4.62	13.32	20.9	20.0	3.7	8.46	9.27	10.0
13	EPS 13	26.1	6.9	26.0	101.0	8.0	2.0	0.73	6.66	0.38	5.0	4	4.0	1.21	20.0
14	EPS 14	25.9	6.9	63.0	105.0	19.0	5.2	1.46	11.34	6.46	14.0	9.8	8.70	bdl	10.0
15	EPS 15	25.3	7.0	20.0	94.0	7.0	2.0	0.49	5.76	0.19	9.0	10.8	8.46	bdl	30.0

Table 1: Results of Water Quality Analysis in Effon Psammite Ridge Spring.

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Temperature	15	2.3	23.8	26.1	24.7533	0.17179	0.66533	0.443
pH	15	3.4	4.3	7.7	6.2667	0.27476	1.06413	1.132
Conductivity	15	105	20	125	48.8667	7.41354	28.71253	824.41
S.Solid	15	38	82	120	98.9333	3.27395	12.67994	160.781
T.Hardness	15	56	6	62	25.6667	4.75161	18.4029	338.667
Calcium	15	14.4	1.6	16	6.2933	1.0572	4.0945	16.765
Magnesium	15	7.53	0	7.53	2.4067	0.63249	2.44964	6.001
Sodium	15	7.74	5.58	13.32	7.812	0.57455	2.22523	4.952
Potassium	15	20.71	0.19	20.9	3.3567	1.36391	5.28238	27.904
Chloride	15	19	5	24	14.5333	1.34117	5.19432	26.981
Phosphate	15	11.25	3.7	14.95	8.4533	1.03112	3.9935	15.948
Sulphate	15	5.2	4	9.2	7.6107	0.33898	1.31285	1.724
Nitrate	15	9.27	0	9.27	0.818	0.61141	2.36799	5.607
Bicarbonate	15	69	10	79	25.9333	4.28338	16.58944	275.21
Valid N (listwise)	15							

Table 2: Descriptive Statistical Summary of the Analytical Data.

climate of the study area. The mildly acidic to 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. Generally, the low values of the conductivity are mainly attributed to geochemical processes prevailing in the area. The springs are being recharged from recent precipitation that has low water-rock interactions and low residence time within the aquiferous zones. The hydrochemical trend signifies low mineralized water with low water-rock interactions and residence time. Based on these water types and the presence of Na^{+}, concentration of cations is geogenic in origin and might have come from the interaction of water and the rock or introduced from weathering of rocks into the spring water.

Water chemistry and types

The result of chemical analysis was used to classify the water types present in the Effon Psammite Springs of the study area. Based on the predominance of both cations and anions, a plot on the Piper's Trilinear

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diagram was made. Trilinear plotting systems developed by Piper [13] were used in the study of the water chemistry and quality. Piper diagrams are a combination of cation and anion triangles that lie on a common baseline. A diamond shape between them is used to replot the analyses as circles whose areas are proportional to their TDS [14-20]. The position of an analysis that is plotted on a piper diagram can be used to make a tentative conclusion as to the origin of the water represented by the analysis. The diamond part of a piper diagram may be used to characterize different water types. Generally, groundwater can be divided into four basic types according to their placement near the four corners of the diamond. Water that plots at the top of the diamond is high in ca^{2+} + Mg^{2+} and Cl$^-$+ SO$_4^{2+}$, which results in an area of permanent hardness. Water that plots near the left corner is rich in Ca^{2+} + Mg^{2+} and HCO$_3^-$ and is the region of water of temporary hardness [20-26]. Water plotted at the lower corner of the diamond is primarily composed of alkali carbonates (Na$^+$+ K$^+$ and HCO$_3^-$+CO$_3^{2-}$). Water lying near the right-hand side of the diamond may be considered saline (Na$^+$ + K$^+$ and Cl$^-$ + SO$_4^{2+}$). The water types in the study area were thus designated according to the area in which they occur on the diagram segments (Figure 3). These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are shown in Figures 3 and 4. From the interpretation of this plot, several water types were delineated [27-33]. The water types are Na-SO$_4$-Cl, Na-HCO$_3$, Ca-Na-SO$_4$, Ca-Mg-HCO$_3$-SO$_4$. Based on these water types and the presence of Na$^+$, concentration of cations is geogenic in origin and might have come from the interaction of water and the rock or introduced from weathering of rocks into the groundwater. Piper Trilinear and Durov diagrams (Figure 3 and 4 shows the water types while (Figure 5) is the Stiff diagram showing chemical ions of Effon Spring Water) [34,35].

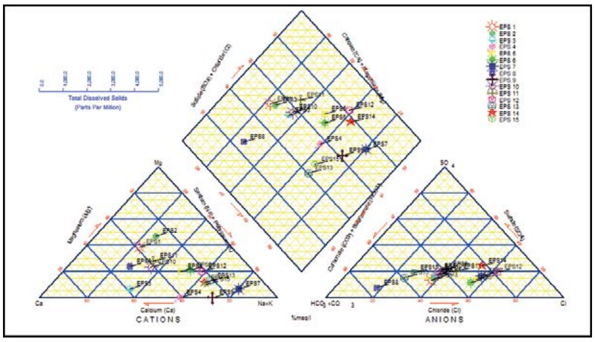

Figure 3: Piper Trilinear Diagrams for Spring Water Samples.

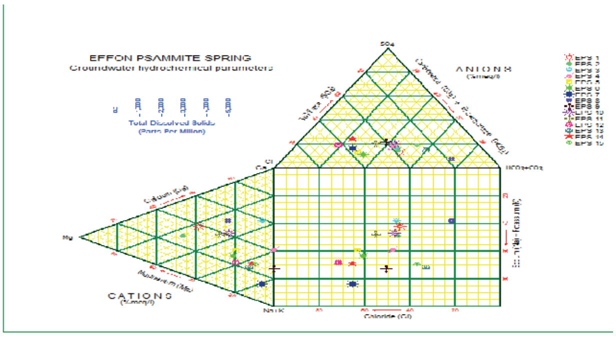

Figure 4: Durov Diagram of the Effon Psammite Spring Water.

	Cond.	SS	TH	pH	Ca^{2+}	Mg^{2+}	Na$^+$	K$^+$	Cl$^-$	PO$_3$	SO$_4$	NO$_3$
Cond.	1											
SS	0.28	1										
TH	0.62	-0.14	1									
pH	0.02	0.21	-0.48	1								
Ca^{2+}	0.59	-0.11	0.95	-0.62	1							
Mg^{2+}	0.56	-0.03	0.9	0.25	0.63	1						
Na$^+$	0.79	0.35	0.12	0.29	0.12	0.15	1					
K$^+$	0.79	0.56	0.13	0.27	0.09	0.21	0.86	1				
Cl$^-$	0.34	-0.12	0.14	0.1	-0.01	0.21	0.35	0.31	1			
PO$_3^-$	0.36	0.02	-0.48	0.11	-0.48	-0.3	-0.08	-0.11	0.13	1		
SO$_4^{2-}$	0.12	0.31	0.04	-0.23	0.04	0.13	0.24	0.29	0.29	0.4	1	
NO$_3^-$	0.93	0.43	0.5	0.17	0.66	0.28	0.87	0.92	0.3	-0.52	0.9	1

Table 3: Correlation analysis results for the samples.

Results also show that strong correlation exist between Na$^+$ and EC (r=0.793), K$^+$ and EC (r=0.905), TH and Mg^{2+} (r=0.901), Na$^+$ and K$^+$ (r=0.857), K$^+$ and NO$_3^-$ (r=0.909), Ca^{2+} and Mg^{2+} (r=0.632), Ca^{2+} and NO$_3^-$ (r=0.6580). Weaker correlations were obtained between Ca^{2+} and EC (r=0.589), Mg^{2+} and EC (r=0.561), K$^+$ and Suspended solids (r=0.563) (Table 3) [36].

Conclusion

This investigation has revealed that except for pH values that are mildly acidic to slightly alkaline in some locations, the physico- chemical characteristics of the spring waters are below the WHO recommended standards for drinking water. The low values of the conductivity are mainly attributed to geochemical processes prevailing in the area. These characteristics make the water suitable for both domestic and industrial usage. The mean concentrations of the cations follow the order: Na$^+$ >Ca^{2+} >K$^+$ >Mg^{2+} while for anions, HCO$_3^-$ >Cl$^-$ >PO$_3^-$ >SO$_4^{2-}$ >NO$_3^-$. The water is mildly acidic to alkaline due to dissociation of bicarbonate with the following water types: Na-SO$_4$-Cl, Na-HCO$_3$, Ca-Na-SO$_4$ and Ca-Mg-HCO$_3$-SO$_4$ which are a reflection of geology and climate of the area.

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It is recommended that effective development of springs should involve thorough examination of their seasonal discharges, including during the summer. In case water supply exceeds use, the surplus waters may be stored for future use in horticulture and to irrigate crop land. Since springs are yet to receive substantial attention, care must be taken to protect the spring from contamination.

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