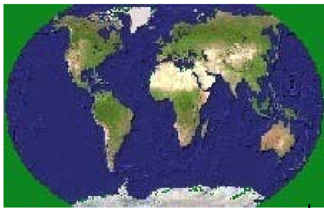

International Journal of Multidisciplinary Research and Development

Volume: 2, Issue: 10, 19-25
Oct 2015
www.allsubjectjournal.com
e-ISSN: 2349-4182
p-ISSN: 2349-5979
Impact Factor: 5.742

A.O. Talabi
Department of Geology,
Ekiti State University,
P.M.B 5363, Ado-Ekiti,
Nigeria

Correspondence
A.O. Talabi
Department of Geology,
Ekiti State University,
P.M.B 5363, Ado-Ekiti,
Nigeria

Hydrochemical and Bacteriological Evaluation of Awefin Springwater Osin-Ekiti, Southwestern Nigeria

A.O. Talabi

Abstract
Awefin Springwater in Osin-Ekiti, Southwestern Nigeria has contributed significantly to domestic and agricultural activities of Osin rural community. The water was consumed without consideration for its potability. This study examined the hydrochemistry and bacterial contents of Awefin springwater with a view to characterize the water and determine its suitability for drinking and irrigation. The methodology entailed collection of 30 samples (3 sets of samples per location) from the spring at interval of 10m downstream into new prewashed polyethylene bottles. Standard method was followed in the collection, preservation and analysis of the springwater samples. Temperature (°C), pH and EC (µS/cm)) were measured in-situ using a Multiparameter portable meter (Testr^{Tm} 35 series). Sodium and potassium were estimated using flame photometer (model: synthronic flame photometer 128) while Ca^{2+} and Mg^{2+} were determined by titrimetric standard EDTA. Argentometric ($AgNO_3$) titration was employed in the estimation of Cl^- concentrations; SO_4^{2-} was by the turbidimetric method while Ultra Violet–visible spectrophotometer was employed in the determination of NO_3^- concentrations. Nutrient agar medium was used to obtain plate count of living bacteria while Coliform count was achieved using a lactose medium inoculated with serial dilution of the sample. Results obtained were compared with internationally and locally approved standards for drinking water while data evaluation was carried out employing SPSS. 17.0. The results revealed that the pH ranged from 8.40 – 11.3, EC from 91 – 138 (µS/cm), TDS and TH ranged from 68. 25 – 103.50 (mg/L) and 12.37 – 21.53 (meq/L) respectively. The pH revealed alkaline water while the EC, TDS and TH have values within approved standards of drinking water. All the major ions concentrations were within approved standard values for drinking water (chemically potable) with major cations in mg/L ranged from1.51 (Mg^{2+}) – 12.13 (Na^+) while the anions was between 0.00(SO_4^{2-}) mg/L and 115.21 (Cl^-) mg/L. The total bacterial counts and coliform counts ranged from 0.7 x 10^2 – 1.62 x 10^5Cfu/100ml and 0.00 – 1.92 x 10^6 Cfu/100ml respectively. The springwater was characterized as NaCl water (90%) with minor CaCl water type (10%). Estimated irrigation quality parameters (Permeabilitry Index (PI), Sodium Adsorption Ratio (SAR) and soluble sodium product SSP) indicated that Awefin springwater was suitable for irrigation while assessment based on Kelly Ratio (KR) and Magnesium Adsorption Ratio (MAR) revealed 10% compliance. This study revealed that Awefin springwater was low mineralized, chemically potable but polluted bacteriologically. The PI, SAR and SSP signified good quality springwater for irrigation purposes while KR and MAR were indicative of non suitability.

Keywords: Springwater, potability, coliform, salinity hazard, low mineralized.

1. Introduction

Springwater has been used for basic survival (domestic purposes), medicinal uses, entertainment and pleasure amongst other functions of ensuring continuity and functioning of ecosystem. Most part of Ekiti State including the study area is underlained by crystalline rocks such as gneisses, schists, granites, charnokites and pegmatites which constitute the major aquiferous units (crystalline basement aquifers) of the state [1]. The crystalline rocks do not have primary porosity. The weathered and fractured horizons act as the water bearing zones and supply water to wells and boreholes. Limited seasonal surface water resources and erratic rainfall has increased the dependence on the groundwater resources. Awefin Springwater in Osin-Ekiti, Southwestern Nigeria is a perennial springwater that has contributed significantly to domestic and agricultural activities of Osin rural community especially during dry season when most surface water and shallow well water must have dried off.

World Health Organization (WHO) reported that in developing countries over three million people (90 % are children under 5) die every year because of waterborne diseases [2, 3]. Access to safe drinking water remains an urgent necessity in the study area in view of the crystalline nature of the terrain in which the rocks are non-porous except when fractured and alternative sources of water (surface water and shallow hand dug wells) are unreliable due to seasonal variations. Access to clean water is a human right and a basic requirement for economic development. Springwater is considered as one of the safest kind of water supply that could be enjoyed by humans arising from natural protection against pollution by the covering layers; only minor water treatment is required [4]. However, quality deterioration can arise from domestic pollution (disposal of wastes, leaching of sewers materials), agricultural pollution (leaching of nutrients, pesticides and fertilizers), industrial pollution (disposal of effluents in stream or land), geogenic contamination (high concentration of As, Fe, F, salinity and water hardness) and alteration of chemistry of the springwater through mixing of waters of different composition.

It has been observed that many of the rural community especially in developing countries consumed water that has not been certified potable. This disastrous trend in which water has being taken for granted was equally observed in Osin rural community. No water can be accepted as safe for drinking purpose except it has been certified to be chemically and bacteriologically potable. Hence, Awefin springwater has been sampled and evaluated to characterize the water, ascertain its potability and suitability for irrigation purposes.

1.1 Geology and Location of study

Osin-Ekiti is located in the Northeastern part of Ekiti State, Southwestern Nigeria. It lies between latitudes $7°53.48^{1}$N and $7°53.53^{1}$N and Longitudes $5°21.27^{1}$E and $5°21.37^{1}$E ((Fig. 1). The study area has tropical climate and rain forest vegetation. The average annual rainfall is about 1300mm. The rainy season exhibits bimodal distribution within a hydrologic year with the two picks in June to July and September to October rainy periods respectively. The two wet seasons are normally separated by a short draught period designated as August break. The dry season spans from November to April during which little or no rainfall is experienced [5]. The study area is rugged with topographic elevation ranging from 345.0 to 375.0 m above mean sea level. Geologically, the study area belongs to the Archean-Protrozoic basement rocks of southwestern Nigeria. Only charnockite which exhibits dark green to greenish-grey colour outcropped in the area. The charnockites in Ekiti-State were categorized into three groups based on structural characteristics [6]. These are the coarse grained, massive-fine grained and gneissic fine grained types. The coarse grained variety outcropped in the study area.

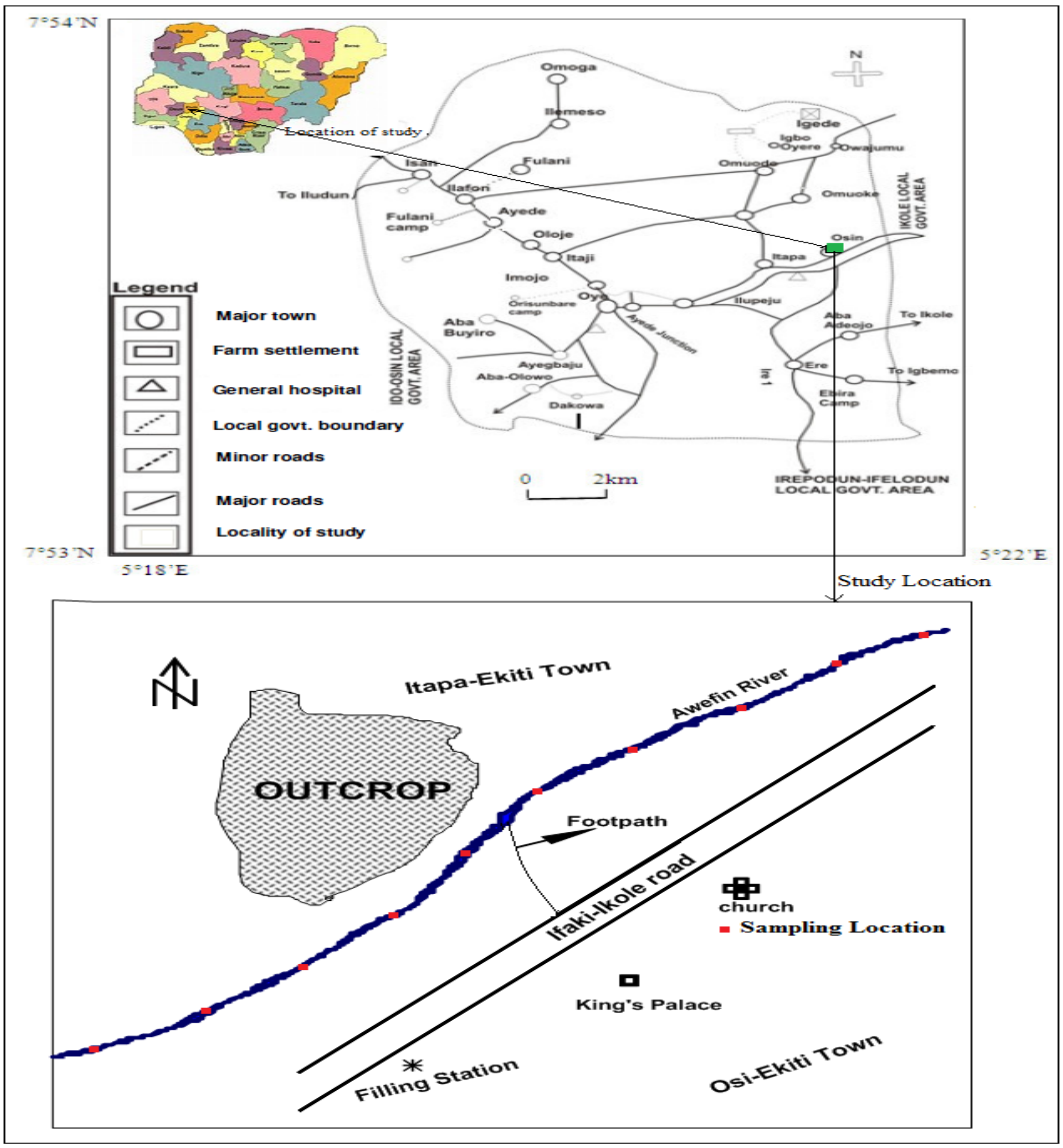

Fig 1: Map showing the study area and sampling locations [modified after 7].

2. Materials and methods

Field and Laboratory operations constitute the major methods employed in this research. Field operations entailed reconnaissance survey during which, visit to the site of the springwater was carried out and decision with respect to sampling operations was taken. Subsequently, thirty (30) water samples (3 samples per location) were collected from the spring at interval of 10m downstream into a new polyethylene bottles that have been dry-washed with dilute hydrochloric acid and rinsed thrice with the springwater sample at each location before filling to capacity and then labeled accordingly (Fig. 1). The three set of samples per location were used for cations, anions and bacteriological analyses respectively. Samples for cations determination were acidified with concentrated Nitric acid and all samples were refrigerated below 4°C in the Laboratory prior to analysis. The standard method followed in the collection, preservation and analysis of the springwater samples was in accordance with [8]. At each location on the field, field parameters (temperature (°C), pH and EC (µS/cm)) were measured using a Multiparameter portable meter (Testr^{Tm} 35 series). EC and TDS are related in natural waters while TH is controlled principally by the concentrations of Ca^{2+} and Mg^{2+}. TDS and TH were estimated exploiting the relationships; TDS (mg/L) ~ 0.75EC (µS/cm) while TH = Ca+Mg*50 [9] where, TH is expressed in meq/L and the concentrations of the constituents are expressed in meq/L. In this research all laboratory analyses were carried out at Fatlab Nigeria Company Ltd., Ibadan Nigeria. Sodium and potassium were estimated using flame photometer (model: synthronic flame photometer 128) while Ca^{2+} and Mg^{2+} were determined by titrimetric standard EDTA. Argentometric titration ($AgNO_3$ titration) was employed in the estimation of Cl^- concentrations while SO_4^{2-} was analysed using the turbidimetric method [10]. Ultra Violet–visible spectrophotometer was employed in the determination of NO_3^- concentrations [11]. The samples were analyzed for total bacteria count and identified bacteria. Nutrient agar medium was used to obtain plate count of living bacteria (viable cell count) while Coliform count was achieved using a lactose medium inoculated with serial dilution of the sample. The appearance of acid and gas after 24 hours at 37 ºC was taken as positive indication of the presence of coliform bacteria; results were expressed as number of colonies per 100 ml. Results obtained (chemical and bacteriological) were compared with international [2] and local [12] approved standards for drinking water as part of data evaluation process. Furthermore data from the various analyses were subjected to statistical evaluation employing SPSS. 17.0. Irrigation quality assessment was by estimating the following irrigation parameters; Sodium Absorption Ratio (SAR), Magnesium Absorption Ratio (MAR), Kelly Ratio (KR), Permeability index (PI) and Wilcox diagram [13].

The Sodium Adsorption Ratio (SAR) was calculated by the following equation given by [14] as:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca+Mg)}{2}}} \qquad (1)$$

Where, all the ions are expressed in meq/L.

The Magnesium Adsorption Ratio (MAR) was calculated by the equation [9] as:

$$MAR = \frac{Mg*100}{Ca+Mg} \qquad (2)$$

Where, all the ionic concentrations are expressed in meq/L.

Kelly Ratio (KR) was calculated using the equation [15] as:

$$KR = \frac{Na}{Ca+Mg} \qquad (3)$$

Where, all the ionic concentrations are expressed in meq/L

The permeability index was estimated according to [16] using the following equation:

$$PI = \frac{\left(Na+\sqrt{HCO_3}\right)*100}{Ca+Mg+Na} \qquad (4)$$

Where, all the ions are expressed in meq/L while the Soluble Sodium Percentage (SSP) was estimated employing the following equation:

$$SSP = \frac{Na^+ + K^+ *100}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \qquad (5)$$

3. Results and Discussion

The results of field measured/estimated parameters and that of the bacteriological analysis alongside with [2] and SON (2007) approved standards are presented in Table 1 while those for the chemical parameters are in Table 2. The results revealed that the pH ranged from 8.40 – 11.3 (av. 9.02), EC from 91 – 138 (av. 99.4) (µS/cm), TDS and TH ranged from 68. 25 – 103.50 (av74.55) (mg/L) and 12.37 – 21.53 (av. 16.10) (meq/L) respectively. The result indicated alkaline water with 30% of the sampled springwater exceeding the [2] approved standard value while 60% exceeded the [12] approved value for drinking water. There are no health based guidelines for pH. WHO stated that pH usually has “no direct impact on consumers.” However, pH that is not within approved standard may result into corrosion of pipes. Failure to minimize corrosion can result in the contamination of drinking water and have adverse effects on its taste and appearance. The EC, TDS and TH have values within both the [2, 12] approved standards. The low values of the EC and TDS are indicative of low mineralized springwater with low residence time signifying recharge from recent precipitation. All the major ions average concentrations in mg/L (Ca^{2+} (2.62), Mg^{2+} (2.29), Na^+ (8.81, K^+ (5.26), HCO_3^- (29.89), SO_4^{2-} (0.05), Cl^-(76.87) and NO_3^- (0.34) are within approved standard values for drinking water. The low values of TDS are a reflection of the low concentrations of major ions. In general, the major cations and anions order of concentrations were $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ and $Cl^- > HCO_3^- > NO_3^- > SO_4^{2-}$ respectively (Fig. 2). The springwater has TH range of 12.37 – 21.53 (av. 16.01) mg/L. Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather. Water hardness is predominantly as a result of calcium and magnesium cations in water though other cations (aluminium, barium, iron, manganese, strontium and zinc) also contribute [17]. In accordance with [18] classification of water hardness, water containing calcium carbonate at concentrations below 60mg/L is generally considered as soft and Awefin springwater is in this category. The trace metals were of low concentrations except for the Fe (0.10 – 1.11) mg/L and Mn (0.00 – 0.65) mg/L that exceeded the approved [2] standard values in few locations. Iron and manganese naturally, are components of soils, rocks and minerals. However, during rock-water interactions in the aquifers, the dissolved metals

(Fe and Mn) are released into the water. In accordance with [2] approved standards, the usefulness of water may become seriously impacted at Fe and Mn concentrations of 0.3mg/L and 0.05mg/L respectively. At or above these concentrations such affected water may have a metallic taste and the plumbering fixtures may become stained. At these concentrations however, the health risk of dissolved Fe and Mn in drinking water is insignificant.

Table 1: Results of physical and Bacteriological parameters of Awefin Spring water

code	Temp. (°C)	pH	EC (µS/cm)	TDS (mg/L)	TH	TBC (cfu/100ml)	E-Coli cfu/100ml
SO1	24.1	11.3	93	69.75	19.63	$0.7x10^2$	$1.92x10^6$
SO2	23.7	9.8	96	72	17.58	$1.2x10^2$	0
SO3	23.8	8.8	95	71.25	16.38	$3.5x10^2$	$5.1x10^3$
SO4	24	9.3	96	72	16.29	$1.62x10^5$	$1.61x10^6$
SO5	23.9	8.4	91	68.25	12.65	$1.06x10^4$	0
SO6	24	8.4	138	103.5	21.53	$4.4x10^3$	0
SO7	23.8	8.5	105	78.75	14.87	$1.02x10^5$	$1.2x10^4$
SO8	24.4	8.6	93	69.75	16.23	$6.5x10^3$	130
SO9	24.7	8.6	91	68.25	12.37	$4.0x10^3$	$1.4x10^3$
SO10	24	8.5	96	72	13.48	$5.6x10^3$	$1.2x10^4$
Min	23.7	8.4	91	68.25	12.37	$0.70x10^2$	0
Max	24.7	11.3	138	103.5	21.53	$1.62x10^5$	$1.92x10^6$
Mean	24.04	9.02	99.4	74.55	16.1	$2.95x10^4$	$3.56x10^5$
Stdev	0.3	0.92	14.14	10.6	2.95	$5.58x10^4$	$7.46x10^5$
[2]	-	6 - 9	1500	1000	500	0	0
[12]	-	6.5-8.5	-	500	250	0	0

Table 2: Results of Chemical parameters of Awefin Spring water

code	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Mn (mg/L)	Fe (mg/L)	Cu (mg/L)	Zn (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	NO_3 (mg/L)
SO1	2.82	3.02	8.01	4.32	0	0.1	0	0.02	24.4	0.065	57.6	0.204
SO2	2.63	2.64	8.22	4.24	0	0.11	0.01	0.01	36.6	0.001	72	0.573
SO3	2.52	2.42	8	4.53	0	0.22	0.01	0.02	36.6	0.014	115.21	0.239
SO4	2.5	2.41	8.21	4.55	0	0.34	0	0	24.4	0.011	64.83	0.098
SO5	2.01	1.83	8.33	4.56	0	0.76	0	0.01	30.52	0.016	93.6	0.211
SO6	3.56	3.03	12.13	9.56	0	1.03	0.02	0.01	30.51	0.123	84.62	0.467
SO7	2.43	2.11	9.35	6.25	0.65	1.11	0.01	0.01	30.5	0.088	64.8	0.819
SO8	2.56	2.36	8.52	4.81	0.1	0.24	0	0	24.4	0.103	72.03	0.208
SO9	2.43	1.51	8.45	4.78	0.21	0.42	0.01	0	24.41	0.072	86.4	0.239
SO10	2.76	1.58	8.92	4.96	0.32	0.34	0	0.01	36.6	0.032	57.6	0.344
Min	2.01	1.51	8.00	4.24	0.00	0.10	0.00	0.00	24.40	0.00	57.60	0.10
Max	3.56	3.03	12.13	9.56	0.65	1.11	0.02	0.02	36.60	0.12	115.21	0.82
Mean	2.62	2.29	8.81	5.26	0.13	0.47	0.01	0.01	29.89	0.05	76.87	0.34
Stdev	0.40	0.54	1.24	1.61	0.21	0.37	0.01	0.01	5.34	0.04	18.20	0.22
[2]	200.00	-	200.00	200.00	0.40	0.30	1.00	3.00	240.00	250.00	250.00	50.00
[12]	-	-	200.00	-	0.20	0.30	1.00	3.00	-	200.00	250.00	50.00

3.1 Correlation Analysis of Awefin Springwater

Correlation analysis of Awefin springwater as presented in Table 3, revealed significant correlations of K^+, Na^+, Mg^{2+}, SO_4^{2-}, NO_3^- and TH. Nitrate concentrations in water have been attributed to surface/near surface phenomena arising from anthropogenic activities [19]. This trend of correlation indicates contributions from geogenic as well as anthropogenic sources of solute to the springwater under study. In addition, since NO_3^- has positive contributions with Na^+ (0.417), K^+ (0.425), HCO_3^- (0.433) and EC (0.420) are reflections of surface anthropogenic activities that were prevalent in the spring. Chloride has negative and very low correlations with all physico-chemical parameters of Awefin spring except Ca^{2+} signifying geogenic source of the two ions as solute contributions into the springwater.

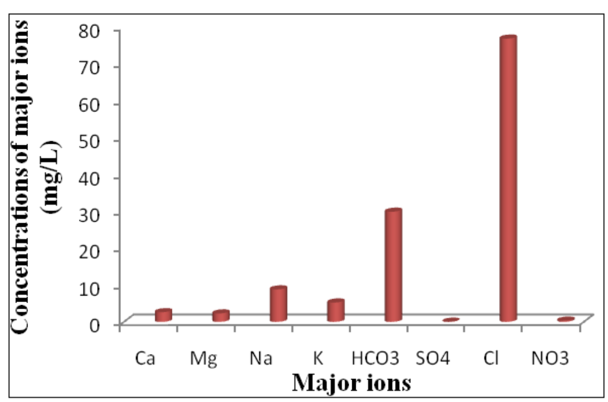

Fig 2: Major ions concentrations of Awefin springwater

Table 3: Correlation Analysis of the physico-chemical Parameters of Awefin spring

	EC	TDS	TH	Ca	Mg	Na	K	HCO3	SO₄	Cl	NO₃
EC	1	-	-	-	-	-	-	-	-	-	-
TDS	1.000	1	-	-	-	-	-	-	-	-	-
TH	.643	.643	1	-	-	-	-	-	-	-	-
Ca	-.105	-.105	.037	1	-	-	-	-	-	-	-
Mg	.484	.484	.964	.088	1	-	-	-	-	-	-
Na	.969	.969	.487	-.227	.300	1	-	-	-	-	-
K	.976	.976	.511	-.154	.341	.990	1	-	-	-	-
HCO_3	.121	.121	-.042	.442	-.088	.079	.042	1	-	-	-
SO_4	.583	.583	.349	-.309	.222	.670	.693	-.443	1	-	-
Cl	.052	.052	-.110	.740	-.069	.007	.063	.285	-.158	1	-
NO_3	.420	.420	.118	-.162	.070	.417	.425	.433	.260	-.190	1

Chloride has negative and very low correlations with all physico-chemical parameters of Awefin spring except Ca^{2+} signifying geogenic source of the two ions as solute contributions into the springwater.

3.2 Mechanism controlling Awefin springwater chemistry

The springwater under study flows like a river and as such carried weathered materials from the upstream to downstream section. The geochemical processes of the springwater are controlled by numerous factors including climate, lithology, topography, vegetation and human activities [20]. In this study the source of the dissolved ions in the springwater was evaluated employing Gibb's diagram [21]. All sampled water fell in the weathering zone of the Gibb's diagram (Fig. 3) indicating that chemical weathering of the rock forming minerals was the main process that contributed ions to the springwater.

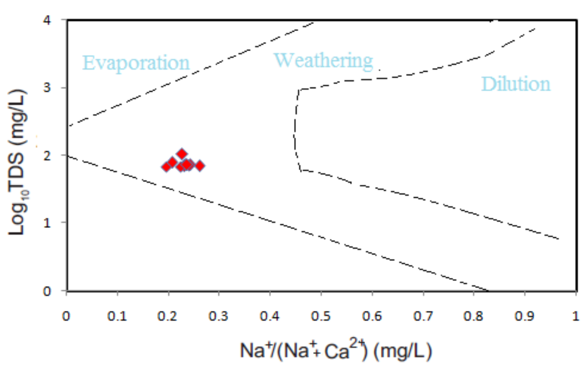

Fig 3: Plot of Log (TDS) vs. $Na^+/Na^+ + Ca^{2+}$

In addition, [22] studied silicate weathering reactions employing Na/Cl molar ratio. He indicated that molar ratio>1 was an indication that Na^+ was released from silicate (Feldspar) weathering in the process of exchange of magnesium and calcium in water with Na and K in rock (cation-anion exchange reaction). Values of Na/Cl molar ratio<1implied another source of contribution of Cl into the water system [23]. Also, if silicate weathering occurred thereby releasing Na^+ into the water, HCO_3^- would be the most abundant anion arising from the reaction of silicate minerals with carbonic acid in the presence of water [24] which released HCO3- as presented in the equation below [25];

$2NaAlSi_3O_8 + 2CO_2 + 11H_2O = Al_2Si_2O_5\ (OH)_4 + 2Na^+ + 2HCO_3^- + 4H_4SiO_4$ (6)

In this study, the molar ratios of Na/Cl were <1 (Table 5) for all water samples and Cl^- was the most abundant anion with average concentration of 76.87mg/L, an indication of other source of contribution of Cl^- anion into Awefin springwater. This observation indicated that apart from ions contribution to Awefin springwater due to weathering arising from water – rock interactions, parts of the ions are consequent of anthropogenic/surface activities.

Furthermore, principal component analysis (Table 4) revealed that Cl, K, Na constitute significantly the geogenic ions source of Awefin springwater with a loading factor of 59.43% while NO_3 and K with a loading factor of 35.94% were of anthropogenic sources. The principal component analysis supported the early submission that the sources of ions input into Awefin springwater were both geogenic and anthropogenic.

3.3 Bacteriological Evaluation of Awefin springwater

Water can be easily contaminated in different ways trough public ignorance of environment and related considerations, lack of provisional basic social services, indiscriminate disposal of increasing antropogenic wastes, unplanned application of agrochemicals, and discharge of improperly treated sewage/industrial effluents result in excess accumulation of pollutants on the land surface and contamination of water resources [26].

Table 4: Principal Component Analysis

Parameters	*Component*		
	PC 1	PC 2	PC 3
Ca	-0.0021	0.0234	0.0021
Mg	-0.0009	0.0184	-0.0137
Na	0.0061	0.0839	-0.0099
K	0.0128	0.1094	-0.0312
HCO3	0.0926	0.0343	0.9944
SO4	-0.0003	0.00185	-0.0042
Cl	0.9899	-0.1104	-0.0883
NO3	-0.0017	0.0069	0.0199
EC	0.1061	0.9832	-0.0402
% Variance	59.43	35.94	4.55
Cum. %	59.43	95.37	99.92
Range of assigned factor	-0.0021 - +0.9899	-0.1104 - +0.9832	-0.0042 - +0.9944
Loading Extracted Factor	59.43 and 59.43	35.94 and 95.37	4.55 and 99.92
Controlling variables	Cl, EC , K, Na	NO_3 and K	HCO_3 , NO_3

In Ekiti State, study has indicated that the groundwater system was fresh, low mineralized but polluted bacteriologically as a result of surface phenomena of improper disposal of waste and human faeces [27]. In the present research, TBC ranged from $0.70x10^2$ - $1.62x10^5$ (av. $2.95x10^4$) cfu/100ml while E-Coli were between 0 and $1.92x10^6$ (av. $3.56x10^5$) cfu/100ml. The result supported the early submission of [27]. However, E-Coli variability was a reflection of variable anthropogenic effects downstream Awefin springwater. Though faeces were not littered around the spring but surface runoff intermingling with the spring during rainy season could contribute to the high bacterial pollution apart from domestic activities including oil palm production and washing of cloths/fetching with individual fetcher. The presence of any fecal coliform in drinking water is of immediate concern as many diseases can be spread through fecal transmission. The risk of illness dictates that the water must be boiled to kill the organisms before it is safe to drink.

3.4 Characterization of Awefin springwater

Chemical data of water samples from Awefin spring were plotted on Piper – tri- linear diagram (Fig. 4). The Piper diagram [28] revealed the analogies, dissimilarities and different types of water in the study area. Sodium and chloride are the dominant cations and anions respectively. The major water type of Awefin spring is NaCl with minor CaCl water.

3.5 Irrigation quality assessment

Irrigation maintains moisture in the soil which is necessary for the germination of seeds. In Osin-Ekiti, especially in the dry season, Awefin spring has been used for irrigation providing insurance for the short period of droughts. Geochemical data from this study were subjected to irrigation assessment using estimated irrigation parameters as presented in Table 5. The result revealed that SAR ranged from 0.18 – 0.28 (av. 0.22), MAR from 48.83 - 64.09 (av 58.82), KR from 0.89 - 1.49 (av. 1.21) while PI and SSP ranged from 232.38 - 319.46 (av. 281.79) and 40.89 – 49.83(av. 45.81) respectively. In addition to these irrigation parameters, EC and Na are vital to irrigation quality assessment of water. EC ranged from 91 – 138 (av. 99.4) (µS/cm) and Na is between 8.00 and 12.13 (av. 8.81) mg/L.

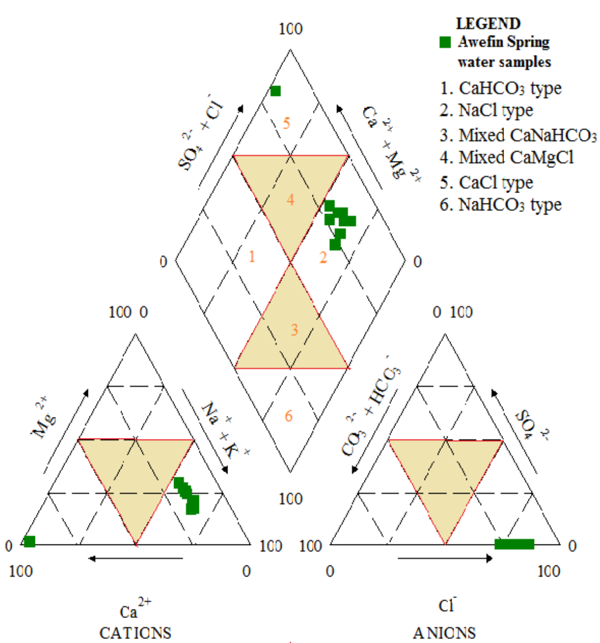

Fig 4: Piper diagram of Awefin springwater

Classification of irrigation water based on salinity hazard indicates that water with EC between 11 and 250µS/cm as excellent for irrigation. Water with high salinity is toxic to plants. Awefin springwater was therefore excellent for irrigation based on salinity hazard. Furthermore, Wilcox plots (Fig.5) supported this fact as Awefin springwater fell into excellent to good category. In addition soluble sodium percent (SSP) that is also used to assess sodium hazard varied from 40.89 – 49.83(av. 45.81) % which is less than the maximum permissible value of 60%. Water with a SSP >60% may result into sodium accumulation in the soil (and subsequent break down in the soil's physical [29]. The Sodium adsorption ratio (SAR) values of Awefin springwater were <10. SAR is a ratio of the sodium (detrimental element) to the combination of calcium and magnesium (beneficial elements) in relation to known effects on soil dispersibility. Internationally, SAR with value above 6 is accepted as a level which soil permeability and structural stability may be affected [30]. Thus Awefin springwater is excellent for irrigation based on SAR assessment. Further assessment of irrigation quality of Awefin springwater employing Kelly Ratio revealed that the water was not suitable for irrigation as KR was >1 in 90% of the sampled springwater. The result indicated that there was excess Na^+ over Ca^{2+} and Mg^{2+} [31]. Similarly, the values of MAR of Awefin springwater in present study are above the acceptable limit of 50% except in location SO10 with 48.83% indicating that about 90% of sampled springwater was unsuitable for irrigation purposes [32]. Permeability Index has been employed in irrigation assessments of water [16]. Values of PI in this study were all greater than 75 and as such fell into class II of this irrigation classification indicating that the springwater was suitable for irrigation [33].

Table 5: Irrigation Parameters and Na/Cl Molar ratio

code	SAR	MAR	KR	PI	SSP	Na/Cl
SO1	0.28	64.09	0.89	279.09	40.89	0.14
SO2	0.24	62.59	1.02	313.62	43.71	0.11
SO3	0.23	61.55	1.06	319.46	43.94	0.07
SO4	0.23	61.64	1.10	274.67	44.65	0.13
SO5	0.19	60.28	1.43	292.43	49.47	0.09
SO6	0.21	58.65	1.23	232.38	43.84	0.14
SO7	0.19	59.14	1.37	271.45	47.05	0.14
SO8	0.23	60.57	1.14	268.33	45.26	0.12
SO9	0.18	50.88	1.49	269.68	49.83	0.10
SO10	0.19	48.83	1.44	296.80	49.43	0.15
Min	0.18	48.83	0.89	232.38	40.89	0.07
Max	0.28	64.09	1.49	319.46	49.83	0.15
Mean	0.22	58.82	1.21	281.79	45.81	0.12
Stdev	0.03	5.01	0.21	25.18	3.01	0.03

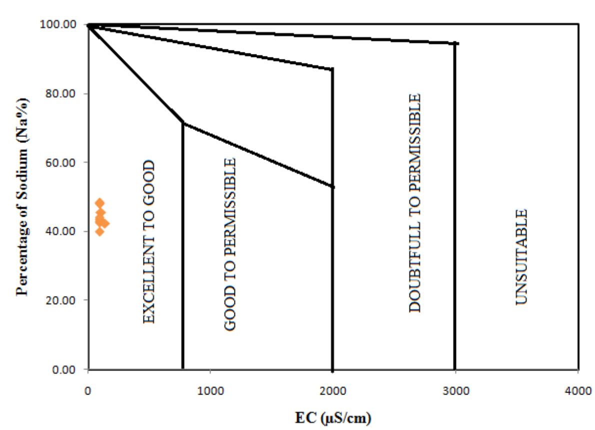

Fig 5: Wilcox Diagram for irrigation classification of Awefin Spring (Wilcox, 1950)

4. Conclusion

This study was on Hydrochemical and Bacteriological Evaluation of Awefin Springwater with a view to characterize the water, determine its potability and suitability for irrigation. The springwater was found to be majorly NaCl water type

(90%) with minor CaCl type (10%). Weathering of country rocks was responsible for ions in Awefin springwater apart from anthropogenic source. All the major ions concentrations were within approved standard values for drinking water (chemically potable) but polluted bacteriologically. Estimated irrigation quality parameters (PI, SAR and SSP) indicated that Awefin springwater was suitable for irrigation while assessment based on KR and MAR revealed 10% compliance. This study revealed that Awefin springwater was low mineralized, chemically potable but polluted bacteriologically. The PI, SAR and SSP signified good quality springwater for irrigation purposes while KR and MAR were indicative of non suitability.

References

1. Talabi AO, (2013) Mineralogical and chemical characterization of major basement rocks in Ekiti State, SW-Nigeria. RMZ – M&G. Vol. 60 pp. 73–86.
2. World Health Organization (WHO, 2004) "Guidelines for Drinking Water Quality", Vol.1: Recommendations (3rd edn). WHO, Geneva.
3. Akoteyon IS, Omotayo AO, Soladoye O, Olaoye HO (2011) Determination of water quality index and suitability of urban river for municipal water supply in Lagos-Nigeria. Eur J Sci Res 54:263–271
4. Edberg SC, Henri L, John R, "Natural Protection of Spring and Well Drinking Water Against Surface Microbial Contamination. II. Indicators and Monitoring. Parameters for Parasites." Critical reviews in microbiology 23, no. 2 (1997): 179-206.
5. Ayoade JO, (1977). Evaporation and evapotrnspiration in Nigeria. J. Trop. Geo., 44, 9 – 19.
6. Rahaman MA, (1988). Recent advances in the study of the basement complex of Nigeria. In *Precambrian Geol. of Nigeria*, (Eds Oluyide *et al.*), a publication of Geol. Surv. Nigeria. Pp 11-41.
7. Ige OO, Olasehinde PI, (2011) Preliminary assessment of water quality in Ayede-Ekiti, Southwestern Nigeria. Journal of Geology and Mining Research Vol. 3(6), pp. 147-152.
8. APHA, Standard method for the examination of water and waste water (1998). (20^{th} Edition). American public Health Association, Washington, USA.
9. Raghunath IIM, (1987). Groundwater. Second edition; Wiley Eastern Ltd., New Delhi, India, 344 – 369.
10. Clesceri LS, Green berg AE, Eaton AD, (1998) Standard methods for the Examination of water and waste water (20^{th} edition). American Public Health Association, Washington.
11. Rowell DL (1994) Soil Science; Methods and Applications. Longman Singapore Publishers (Pte) Ltd, Singapore, pp55.
12. SON, (2007) Nigerian Standards for Drinking Water Quality. Standard Organization of Nigeria (SON) Publ. NIS. Vol. 554: pp. 30p.
13. Wilcox LV, (1950) Classification and use of irrigation waters. Department of Agriculture, United States, Cicular No 696, Washington D. C., pp: 16.
14. Hem JD, (1991) Study and Interpretation of the Chemical Characteristics of Natural Water.
15. Kelly WP, (1963) Use of saline irrigation water. Soil Science, 95(4): 355 – 391.
16. Doneen LD, (1964) Notes on water quality in Agriculture. Published as a water Science and Engineering. Paper 401. Department of Water Sciences and Engineering, University of California.
17. WHO, (2009) Calcium and magnesium in drinking water: Public health significance. Geneva. World Health Organization (http//:whqlibdoc.who.int/publications/2009/9789241563550_eng.pdf).
18. McGowan W, (2000) Water processing: residential, commercial, light-industrial, 3rd ed. Lisle, IL, Water Quality Association.
19. Adeyemi GO, Adesile AO, Obayom, OM, (2003) Chemical characteristics of some well waters in Ikire, Southwestern Nigeria. Water Resources Journal of the Nigerian Association of Hydrogeologists (NAH) Vol. 14, pp. 12-18.
20. Berner EK, Berner RA, (1996) Global Environment: Water, Air and Geochemical Cycles, Prentice Hall, New Jersey.
21. Gibbs RJ, (1970) Mechanism controlling world water chemistry. Science, 170: 1088 – 1090
22. Meybeck M, (1987) Global chemical weathering of surficial rocks estimated from river dissolved loads. Am. J. Sci. 287:401-428
23. Edet A, Nganje TN, Ukpong AJ, Ekwere AS, (2011) Groundwater chemistry and quality of Nigeria: A status review. Afr. J. Environ. Sci. and Tech. 5(13):1152-1169.
24. Elango L, Kannan R, Senthil KM, (2003) Major ion chemistry and identification of hydrogeochemical processes of groundwater in a part of Kancheepuram district, Tamil Nadu, India. J. Environ. Geo. 10(4):157-166.
25. Tay CK, (2012) Hydrochemistry of groundwater in the Savelugu-Nanton District, Northern Ghana. Environ. Earth Sci. 67:2077-2087.
26. Tiwari AK, Singh PK, Mahato MK, (2013) Chemistry of groundwater and their adverse effects on human health: A review, Indian Journal of Health and Wellbeing, 4(4): 923 – 927.
27. Talabi AO, Ogundana AK, (2014) Bacteriological evaluation of groundwater in Ekiti – State, southwestern Nigeria. International Journal of Scientific & Technology Research, Volume 2, issue 9, pp288 – 293.
28. Piper AM, (1944) A graphic procedure in the geochemical interpretation of water analyses. *Trans. Am. Geophy.* Union 25: 914–928.
29. Fipps G, (2003) Irrigation Water Quality Standards and Salinity management strategies soiltesting.tamu.edu/publications/B-1667.pdf
30. Patterson RA, (1994) On-Site treatment and Disposal of Septic Tank Effluent. Thesis for Doctor of Philosophy. University of New England, Armidable.
31. Ayers RS, Westcot DW, (1985) "Water Quality for Agriculture FAO Irrigation and Drain", 29(1), 1-109.
32. Paliwal KV, (1972). Irrigation with saline water. Monogram no. 2 (new series). New Delhi, IARI, 198.
33. Nagaraju A, Suresh S, Killham K, Hudson-Edwards K, (2006) Hydrogeochemistry of water of Mangampeta Barite Mining Area, Cuddapah Basin, Andra Pradesh, India. Turkish Journal of Engineering and Environment Sciences, 30: 203–219.