Assessment of Hydrochemistry and Groundwater Quality in Ijokodo and It's Environment, Ibadan, Nigeria

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Abstract

The study area occurs within the Precambrian basement complex composed of quartzite, quartz-schist, biotite-andbiotite-hornblende-gneiss (migmatite) as the main rock units. Physiochemical assessment of shallow groundwater in Ijokodo area was carried out to determine its suitability for drinking and irrigation purposes. Thirteen (13) groundwater samples were collected and subjected field measurements of physical parameters followed by chemical analyses methods. The results of the physicochemical and the hydrochemical studies show that the Ijokodo stream is slightly alkaline. The trace metals show varied average results in the streams samples of the study area. Results of AF (<1) show that the Ijokodo streams have not been heavily contaminated. The estimated results of geo-accumulation (<0) also confirmed this. The computed values of SAR on the average indicated that the water phase of the Ijokodo streams contain a slight low sodium hazard of 9.5 and this may not be potentially hazardous for irrigation practices. The result of EC, TDS, MR, Kelly's ratio shows that the water samples are good for irrigation The Gibb's diagrams suggest that chemical weathering of the rock forming minerals is the main process which contributes the ions concentration in the water while, The Wilcox diagram result reveals that all water samples are within the area of excellent to good.

Keyword: Hydrochemistry, Groundwater, Ijokodo, Ibadan.

1. INTRODUCTION

Water resources are equally important for natural ecosystem and human development essential for agriculture, industry, and human existence. Hence, water is an indispensable component for survival of life on earth (Shiklomalov, 1998). This contains minerals, important for humans as well as for earth and aquatic life. Any alterations in water quality may lead to the issue of survival for these organisms. The growing human and environmental influences impact strongly on the quantity and quality of water available in any lake system. The determination of the chemical, physical and biological characteristics of natural water resources to check and maintain the water quality for a healthy survival become an urgent demand everywhere in the world because of the increased demand of water for sustenance of life consequently or population growth, agriculture, and industrial development building construction.

Ijokodo area serve a great economic importance; it provides water for domestic, agricultural, and industrial use, support subsistence and artisanal fisheries surrounded by various communities that discharge their domestic waste directly lake, water. When wastes from different sources are discharged into the water body that alter the physical, chemical, and biological characteristics of the water body in such a way that it may not be useful for the purpose for which it is intended.

The primary concern is the quality of surface water (Ijokodo stream) for the purpose of industrial, domestic uses and agricultural purposes. This is also a measure of the physical, chemical, and biological state of the water as well as human alteration action on the water (Raghunath, 1978). Water quality is a term used here to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical, or biological characteristics of water; for example, limits on the concentrations of toxic substances for drinking water use, or restrictions on temperature and pH ranges for water supporting invertebrate communities (Raghunath, 1978). There is increasing recognition that natural ecosystems have a legitimate place in the consideration of options for water quality management. This is both for their intrinsic value and because they are sensitive indicators of changes or deterioration in overall water quality, providing a useful addition to physical, chemical, and other information (Wilcox, 1955; Schoeller, 1960;1965). The composition of surface and underground waters is dependent on natural factors (geological, topographical, meteorological, hydrological, and biological) in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels. Large natural variations in water quality may, therefore, be observed even where only a single watercourse is involved. Human intervention also has significant effects on water quality. The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all the organic and inorganic material present in the water, together with certain physical characteristics of the water. It is determined by in situ measurements and by examination of water samples on site or in the laboratory. The main elements of water quality monitoring are, therefore, on-site measurements, the collection and analysis of water samples, the study and evaluation of the analytical results, and the reporting of the findings. The results of analyses performed on a single water sample are only valid for the location and time at which that sample was taken. One purpose of a monitoring program is, therefore, to gather sufficient data (by means of regular or intensive sampling and analysis) to assess spatial and/or temporal variations in water quality. The aim of this paper is to establish the level of hydrochemistry Ijokodo stream water, to evaluate the concentrations of selected major, trace and rare elements in the water, to determine the sources selected major, trace and REE elements in the water and to determine the contamination indices of the water samples in Ijokodo area of Ibadan, southwestern Nigeria.

1.1 Geology and Location of the Study Area

The study area is lies on the geographical coordinates of 7° 1' 0" N, 3° 54' 0" E (Fig. 1). The study area occurs within the Precambrian basement complex composed of quartzite, quartz-schist, biotite-andbiotite-hornblende-gneiss (migmatite) as the main rock units Fig 2. The quartzschist covered about 60% of the study area, forming ridges and most of the exposed ones are highly weathered. Samples are medium to coarse grained, jointed, and fractured minerals like quartz, feldspar, and mica. "Topographically, Ibadan city is characterized by undulating terrain with quartzite ridge and Inselbergs of gneisses surrounded by adjoining plains" (Tijani *et. al.*, 2014, Awomeso, 2012). The catchment area of Ijokodo Area is characterized by two distinct seasons: the wet season which occurs between March and October with an average annual rainfall of about 1 250mm and the dry season, from November to February (Tijani *et.al*, 2014). The velocities of the flowing water in the respective catchment drop during the dry season. Ijokodo area has influx of about four through which it receives its various discharges. Apete (northeastern part), Eleyele (southeastern part), Olopomewa (southern part) and Awotan (Northwestern part).

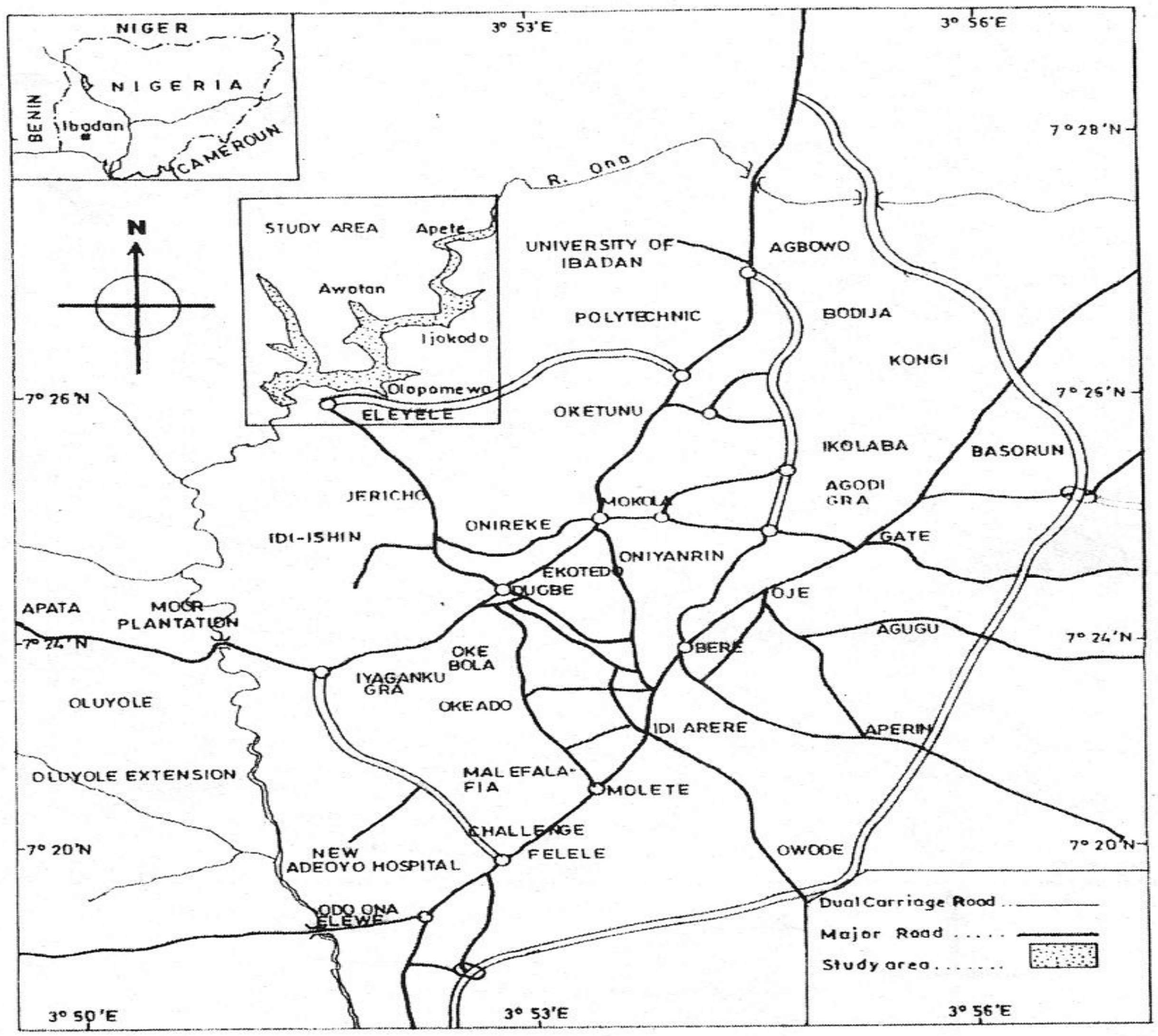

Figure 1. Map of the Study Area (Ijokodo) in Rectangle

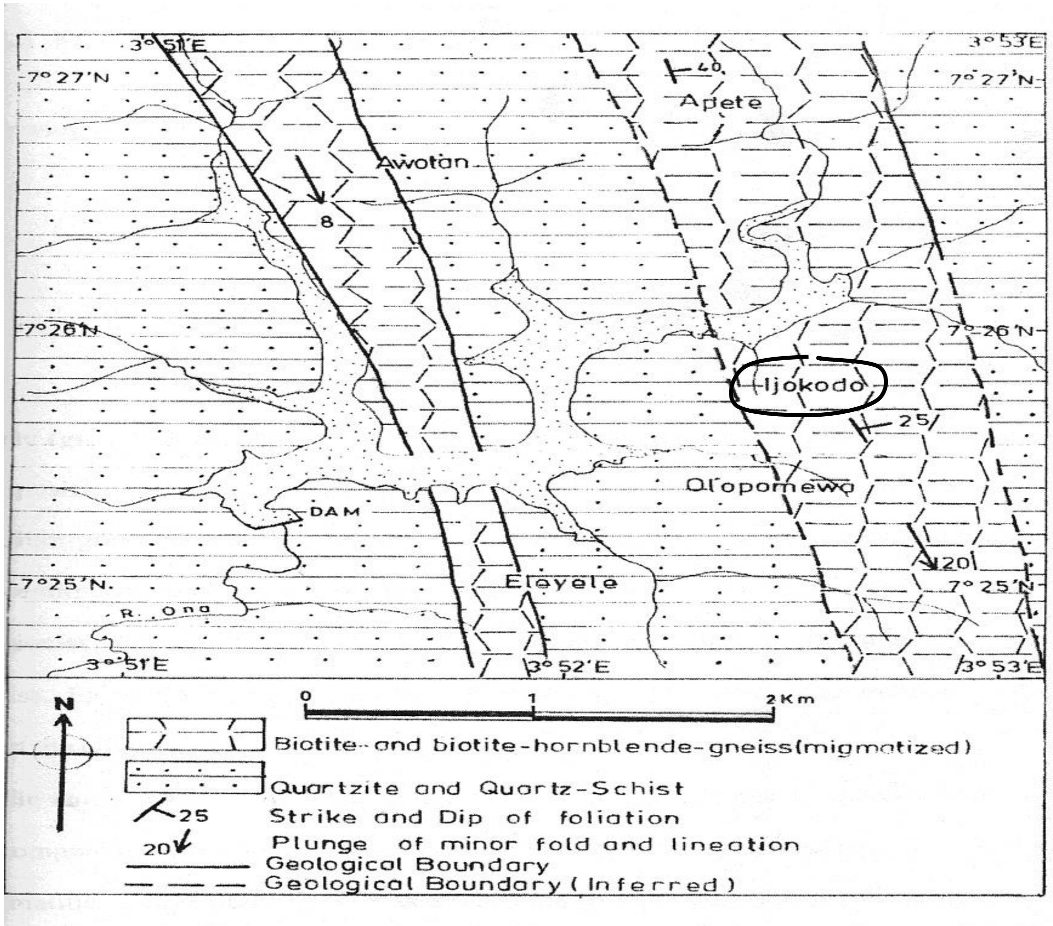

Figure 2. Geological Map of the Study Area. (Geological Survey Map, 1963).

2. MATERIALS AND METHOD

The field work was carried out in Ibadan, Oyo State, South-western Nigeria. Thirteen (13) water samples were collected from the stream of the study area at different locations using Geographic Positioning System (GPS) to determine the position of different locations. During the mapping, the sampling was carried out during dry season. Some physical parameters of water were determined such as Total Dissolved Solids (TDS) using TDS meter, Electrical Conductivity (EC) using EC meter, Alkalinity and Acidity of water using pH meter, water temperature and environmental temperature. Concentrated Nitric Acid (HNO_3) was added to the samples for cations in other to prevent precipitations of cations in the water sample before the water samples were analyzed for the various cations in ACME laboratory, Canada using ICP-MS method, after which they were treated, packaged, and stored before being sent to the laboratory for Hydro-chemical analysis.

Table 1
Irrigation water classifications of the springs

Parameter	Symbol	Unit	Formula	FAO (2006)	Ranges	Water class
Electrical Conductivity	EC	μS/cm		0–3	<250	Excellent
					250–750	Good
					750–2000	Permissible
					2000–3000	Doubtful
					>3000	Unsuitable
Total Dissolved Solid	TDS	mg/L	TDS = 0.64xEC	0–2.000	<1.000	Fresh water
					1.000–10.000	Brackish water
					10.000–100.000	Saline water
					>100.000	Brine water
Percentage Sodium	Na%	meq/L	$Na\% = \frac{\{(Na^{+}+K^{+})100\}}{(Ca^{2+}+Mg^{2+}+Na^{+}+K^{+})}$		0–20	Excellent
					20–40	Good
					40–60	Permissible
					60–80	Doubtful
					>80	Unsuitable
Magnesium Ratio	MR	meq/L	$MR = \frac{(Mg^{2+}\times 100)}{(Ca^{2+}+Mg^{2+})}$		<50	Suitable
					>50	Unsuitable
Kelly Ratio	KR	meq/L	$KR = \frac{\{(Na^{+})}{(Ca^{2+}+Mg^{2+})\}}$		<1	Suitable
					1–2	Marginal suitable
					>2	Unsuitable

2.1 Total Dissolved Solid TDS (ppm)

The concentration of impurities is often termed Total Dissolved Solid (TDS) which is the combination of the sum of all ion particles present in a water body. This includes all dissociated electrolytes that make up a salinity concentration as well as other compounds such as dissolved organic matters. It is often measured in ppm or mg/l and can be determined by using the total dissolved meter.

2.2 Electrical Conductivity EC (μs/cm)

Electrical conductivity of water is the ability of water to conduct an electric current. In other words, it is a measure water's capability to pass an electric current flow. This water ability or capability is directly related to the concentration of ions present in water and these conductive ions come from dissolved organic and inorganic substances such as alkalis, sulphides compounds, carbonated compounds etc. The more the ions present in water the higher the electrical conductivity and the fewer the ions present in water the lesser the electrical conductivity of water. These dissolved substances can either be positively charged ions or negatively charged ions. Major positively charged ions are ion(s) of sodium (Na), calcium (Ca), potassium (K) and magnesium (Mg). The major negatively charged ions are ions of sulphates, carbonates, and bio-carbonates whereas, nitrates and phosphates are minor contributors to water conductivity. Electrical conductivity is a good measure of salinity hazard to crops as it reflects the total dissolved solid in groundwater.

2.3 pH

The pH of pure water is a measure of the relative amount of hydrogen ion (H^+) and hydroxyl ion (OH-) concentrations in water. In other word it is measure of the level of acidity or alkalinity in water. It is expressed in mole per litre and ranges from 0-14 with neutral water at 7, while lower of it (<7) is acidic and pH greater than 7 is basic. Drinking water with a pH ranging from 6.5 to 8.5 is generally considered satisfactory. It is known that water with low pH is tends to be toxic and with high degree of pH it is turned into bitter taste. This depicts that pH with high acidity or alkalinity level in water may result in organism's death as well as the effect of taste of water.

2.4 Temperature

Temperature is the degree of hotness and coldness. It is measured with the aid of thermometer and the unit is degree Celsius (^{0}C). The temperature of water is one of the most important characteristics which determine a considerable extent, the trend of changes in its quality.

2.5 Sodium Absorption Ratio (SAR)

Sodium Absorption Ration is an index of the sodium hazard of water. It is based on the ratio of sodium to calcium and magnesium. SAR is calculated as follows:

$$sAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+M}{2}}}$$

According to A and L Great lakes laboratory Inc., 2002, SAR is classified into three descriptive classes as follows: <3= no potential problem, 4-6= increasing potential problems, >6= severe potential.

2.6 Anthropogenic Factor (AF)

This is a sort of quantification of the degree of contamination relative to either, average crustal composition of the respective metal or to measured background values from geologically similar and contaminated area (Aghazadeh, 2010; Guanxing, 2014). It is expressed as: AF =Cm/Bm where Cm is the measured concentration in water and Bm is the background concentration (value) of metal m, either taken from literature (average shale/average crustal abundance) or directly determined from a geologically similar area. In this study, the average igneous and basement complex were used to compute the AF values (Al-Tabbal, 2012; Hamed, 2011).

Table 2

Parameter for Evaluating Anthropogenic Factor (AF)

1< Cif < 3	7< Cd < 14	Moderate degree of contamination
3 < Cif < 6	7< Cd < 28	Considerable degree of contamination
Cif > 6	Cd > 28	Very degree of contamination

2.7 Index of Geo-accumulation

This is used to evaluate the degree of metal contamination in terrestrial, aquatic as well as marine environments (Tarki, 2016).

It is expressed as: Igeo =Log2 [(Cm)/ (1.5* Bm)]

Where Cm is the measure concentration in water and Bm is the background concentration (value) of metal m, either taken from literature (average shale/average crustal abundance) or directly determined from a geologically similar area. 1.5 is a factor for possible variation in the background concentration due to lithologic differences (Tay, 2012). Igeo could be classified into seven descriptive classes as follows: 5 = very highly strongly contaminated. The latter is an open-end class that include all values above 5, while an Igeo of 6 is said to be indicative of 100- fold enrichment of a metal with respect to baseline value (Mueller, 1979, Tijani *et al.*, 2004). In this study, the Average Igneous Rock Basement Complex- SW Nigeria compositions were used to compute the geo-accumulation values.

Table 3

Parameter for Evaluating Geo-accumalation index

Igeo Values	Class	Quality Descriptions
≤0	0	Uncontaminated
0-1	1	Uncontaminated to moderately contaminated
1-2	2	Moderately contaminated
2-3	3	Moderately to highly contaminated
3-4	4	Highly contaminated
4-5	5	Highly to very highly contaminated
>6	6	Very highly contaminated

3. RESULTS AND DISCUSSION

Some of the trace metals were also analyzed to determine the degree to which they have contaminated the water. Parameters such as Anthropogenic factor, geo-accumulation factor, Correlation Co-efficient and SAR factor were calculated to assess the rare elements contamination.

3.1 Results of Hydrochemical Analyses

The assessment of the major and trace ions will be discussed under the data presentation using tables, pie chart. The simple statistical summaries of hydrochemical analyses were presented in Table 4. From the results of hydrochemical analyses, it shows that Mg^{2+} and K^{+} have respective average values of 7.95ppm and 16.63ppm with respective ranges of 6.74-9.15ppm and 6.65to 26.60ppm in the Ijokodo streams. However, Na and Ca^{2+} show a higher concentration to K and Mg with average values of 38.72ppm and 31.54ppm ppm respectively, in the Ijokodo streams. The higher concentration in Na^{+} and Ca^{2+} in the Ijokodo streams could be attributed to the additional influence of anthropogenic input from the catchments over the geogenic influence on the major cations in the area.

Table 4

Major and Minor ions distribution (cations and Anions) in Ijokodo Stream

Metals (ppm)	20F010	20F011	20F012	20F08	20F09	20F07
Ca^{2+}	30.63	28.73	25.66	30.71	29.67	37.42
K^+	10.75	10.21	6.65	10.06	26.60	26.60
Mg^{2+}	9.15	9.07	6.74	8.74	9.04	7.77
Na^+	29.78	29.00	23.51	28.17	29.52	53.93
Sr	232.51	219.62	157.09	231.52	227.32	189.03
Si	11622	11237	9184	11015	11255	17073
Rb	15.43	14.57	9.89	14.24	14.93	36.87
P	183	170	95.0	167.0	172	5892
Br	115	109	65.0	111	114	106.0

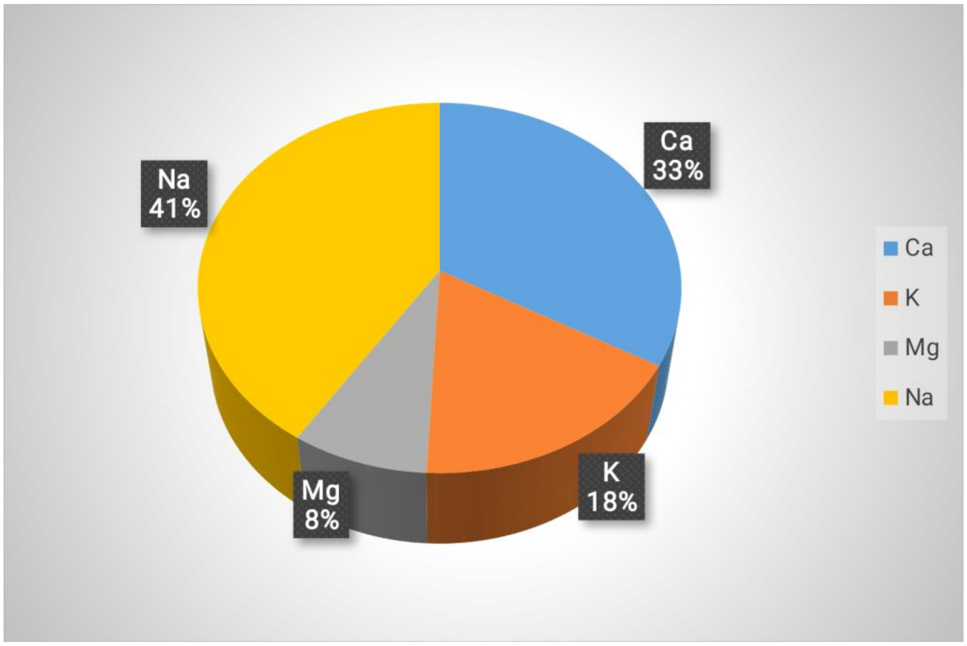

Figure 3. Pie chart showing the distribution of the major cation in Ijokodo stream.

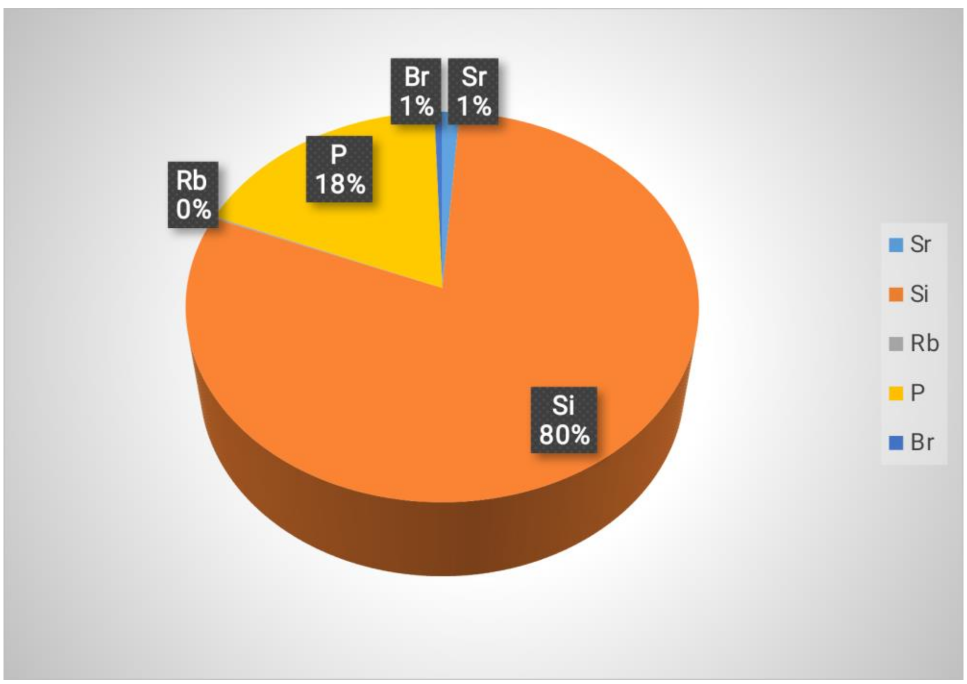

Figure 4. Pie chart showing the Distribution of the Major Anion of Ijokodo Stream Samples

3.2 Assessments of Contamination

3.2.1 Geoaccumalation Index

The geoaccumulation index (I_{geo}) introduced by Muller (1974) was used to assess metal pollution in sediments of Ennore. I_{geo} is expressed as follows: $Igeo = \log2 (Cn / 1.5 \times Bn)$

Where, C_n - measured concentration of heavy metal in the sediment, B_n - geochemical background value in average shale (Todd, 1980) of element n, 1.5 is the background matrix correction in factor due to lithogenic effects. Geoaccumalation index classes to assess sediment quality.

The average crustal abundance and average composition of Basement Rocks were used as background values for the stream samples. The results of Geo-accumulation show that the streams samples in Ijokodo area is practically Low contaminated because the average values are less than 0 for Igeo. However, the Igeo values observed do not totally depict absence of contamination (Muller, 1974). The values only implied that there was no appreciable effect of anthropogenic input on the water samples taken from the feeding streams and the main lake (Todd, 1980).

Table 5

Average Values of geo-accumulation of Water Samples (Basement Complex Composition)

Metal	Values	Summary
Ca^{2+}	-8.155	Low degree of contamination
K^{+}	-11.63	Low degree of contamination
Mg^{2+}	-6.126	Low degree of contamination
Na^{+}	-9.6	Low degree of contamination
Sr	-4.6	Low degree of contamination
Si	-18.8	Low degree of contamination
Rb	-5.3	Low degree of contamination
P	-11.2	Low degree of contamination
Br	-8	Low degree of contamination

3.2.2 Anthropogenic Factor (AF)

The results of Anthropogenic factor (AF) shows that the Ijokodo streams are practically low or uncontaminated because the average values are less than 1 for AF (Table 6). However, the AF values observed do not totally depict absence of contamination (Appelo, 2005). The values only implied that there was no appreciable effect of anthropogenic input on the water samples taken from the study area.

Table 6

Average Values of AF of Water Samples (basement complex composition)

METALS	Values	summary
Ca	0.006	No/Low contamination
Mg	0.025	No/Low contamination
Na	0.0025	No/Low contamination
K	0.001	No/Low contamination
Mn	0.0024	No/ Low contamination
Sr	0.0031	No/low contamination
Si	0.034	No/Low contamination
Rb	0.0034	No/Low contamination
P	0.023	No/Low contamination
Br	0.0044	No/Low contamination

3.2.3 Sodium Absorption Ratio (SAR)

For water to be used for irrigation, the concentration of Ca^{2+} and Mg^{2+} must be higher than that of Na^{2+}. This will cancel the hazardous effect through ion exchange reaction. However, the concentration of Na in the water of the study area is higher than those of Ca and Mg (Sastri, 1994; Akinyem, 2014). This reflects in the average value of SAR estimated (Table 7). The range of SAR in the streams is 5.88 to 11.12 in stream samples of the study area, with an average of 9.5 The average values of SAR in the streams samples of the study area give an indication of Na metal contamination in the streams due to anthropogenic activities in the study area (Saleh, 1999).

Table 7

Simple Statistics of Sodium Absorption Ratio (SAR), in the Ijokodo Sstream

Metals	Ca	Mg	Na	SAR
Average	31.54	7.95	38.72	9.5
Min	25.66	6.74	23.51	5.88
Max	37.42	9.15	53.93	11.12

3.3 Assessment of Physio-chemical Paraments of Water

The results of the physio-chemical parameters which include temperature of the water, electrical conductive, pH of the water body and total dissolved solid of the water samples under investigation are presented in Table 8. The results of the EC of water is its ability to conduct an electric current because of the presence of charged ionic species in solutions. The EC in the study area ranges from 100 to 800µS/cm with an average of 450s/cm. All the samples fall within the WHO (2012) permitted limit (Fig 5). The Total Dissolve Solids (TDS) ranges from 170 to 560ppm with an average of 365ppm (Fig 6). The study shows that all the samples are below the WHO limit of 1500mg/l which suggest that all the samples can be used as drinking water without any health risk. High TDS in water may result in bad taste, odor and color and may also induce unfavorable physiological reactions in the consumer (Raju, 2007).

The result of the pH WHO (2012) permissible limit for pH ranges from 6.5-8.5 for portable water. The pH of the groundwater in the study area ranges from 1.7 to 8.3 with an average of 5.0, this indicates that the ijokodo stream is good for drinking water and irrigation purposes (Fig 7). The temperature ranges from 25^{o}C - 32^{o}C with an average of 28.5. Table 8 shows the temperature of the groundwater samples in the study area. Fig 8, shows the variation in Temperature compared to WHO (2012) maximum permissible limit which is 27^{o}C this shows that samples in the study area exceed the WHO (2012) standard.

Table 8

Physio-Chemical Parameters of the Study Area in Ijokodo tributaries.

Samples	EC (µS/cm)	TDS (ppm)	pH	TEMP(^{0}C)
20F01	600	520	8.1	31
20F02	800	560	8.3	32
20F03	100	410	7.1	25
20F04	700	410	7.2	26
20F07	700	420	7.2	31
20F08	600	540	7.9	28
20F09	100	180	7.5	27
20F10	100	170	1.7	25
20F11	200	170	7.6	26
20F12	200	180	7.8	26
20F15	100	130	7.8	27
20F16	600	540	7.8	25
20F17	600	520	7.7	26

Table 9

Comparison of the Average Hydro-chemical Results with WHO. Standard for Potable Water (1993 and 2006)

Measured Parameters	Average	Min.	Max.	Acceptable Level	Max. Permissible Level
pH	5.00	1.70	8.3	6.5	8.5
TDS(mg/l)	365	170	560	500	1000
EC(µS/cm)	450	100	800	400	1400
Temp (ºC)	28.5	25	32	27	27

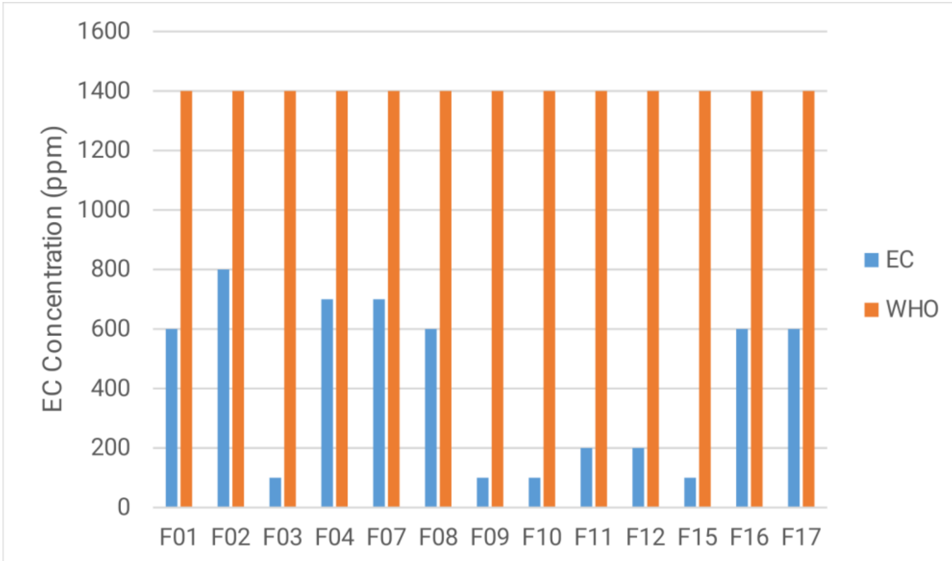

Figure 5. Bar chart of Electrical conductivity in water samples of Ijokodo stream compared with WHO (2012) Standard.

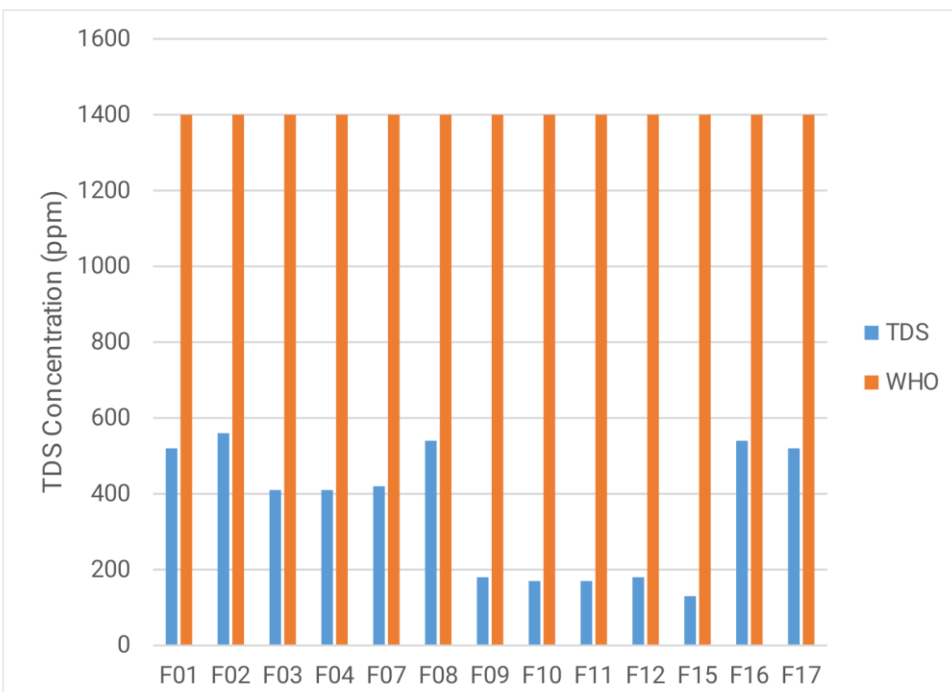

Figure 6. Bar chart of TDS in water samples from Ijokodo stream compared with WHO (2012) Standard.

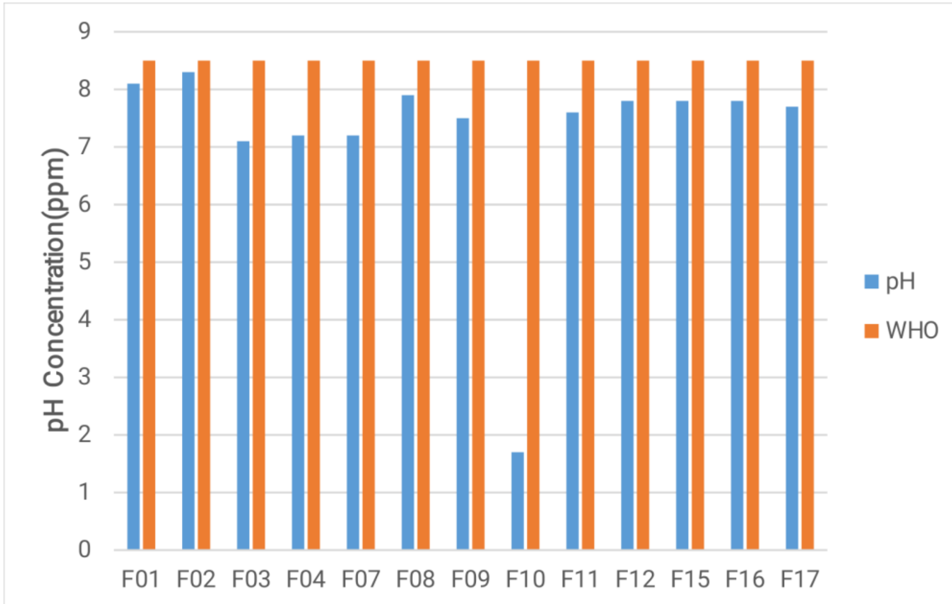

Figure 7. Bar chart showing the variation in pH values of the analyzed water samples

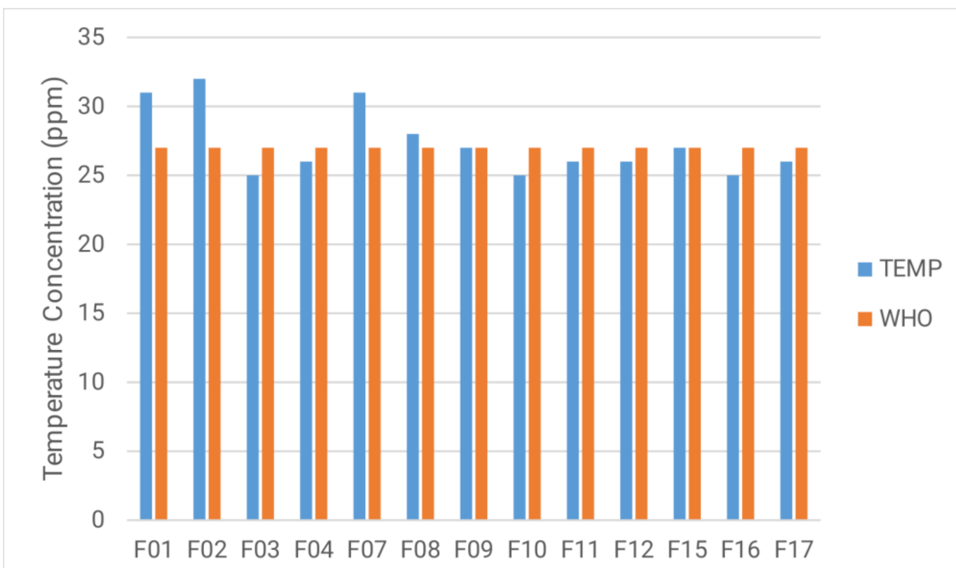

Figure 8. Bar chart of temperature values of the analyzed water samples compared with WHO (2012) Standard.

3.4. Hydro-chemical Evaluation

3.4.1 Gibbs Plot

During weathering and water circulation in rocks and soils, ions leached out and dissolved in groundwater (Naseem *et al.*, 2010). The geological formations, water–rock interaction, and relative mobility of ions are prime factors influencing the geochemistry of groundwater (Yousef *et al.*, 2009; Omotoso, 2012). Gibbs diagram is widely used to establish the relationship of water composition and aquifer lithological characteristics (Gibbs, 1970). In this diagram, ratio of dominant cations is plotted against the values of TDS. Three distinct fields, such as precipitation–dominance, evaporation–dominance, and rock–dominance areas, are shown in the diagram. The chemical data of Ijokodo stream samples are plotted in Gibbs diagram, and it was found that all of the samples fall in the rock–dominance region (Fig.9), thus indicating that precipitation induced chemical weathering along with the dissolution of rock forming minerals which have contributed to the modification of groundwater chemistry (Raju, 2007).

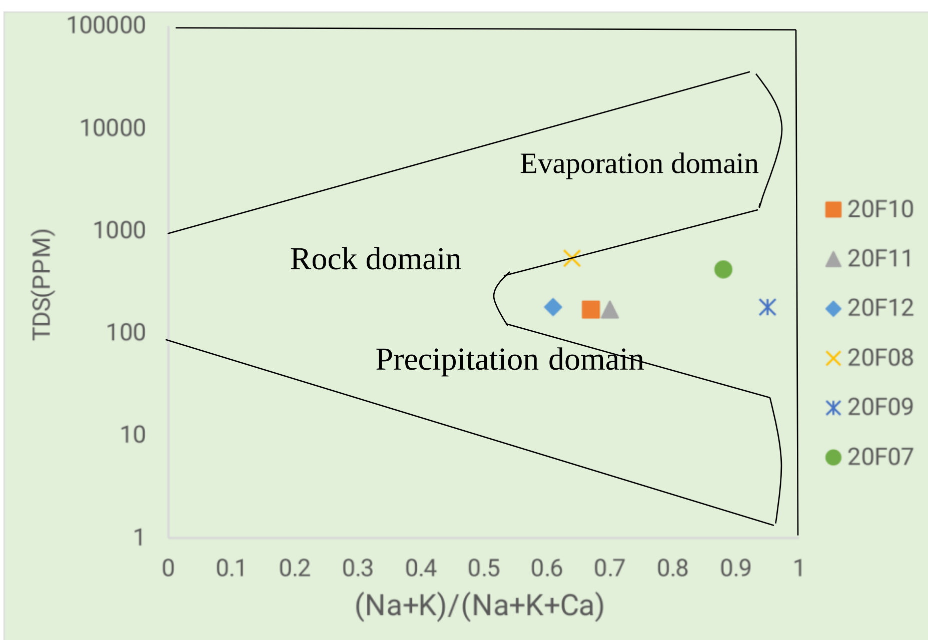

Figure 9. Gibb's diagram of Ijokodo Stream Samples

3.4.2 Wilcox Plot.

Wilcox classified groundwater for irrigation purposes based on percent sodium and EC. Eaton (1950) recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained. The Wilcox diagram (Fig. 10) result reveals that all water samples are within the area of excellent to good except for sample 20F07 (Permissible to Doubtful), thus, all the water samples can be used for irrigation (Wilcox, 1955).

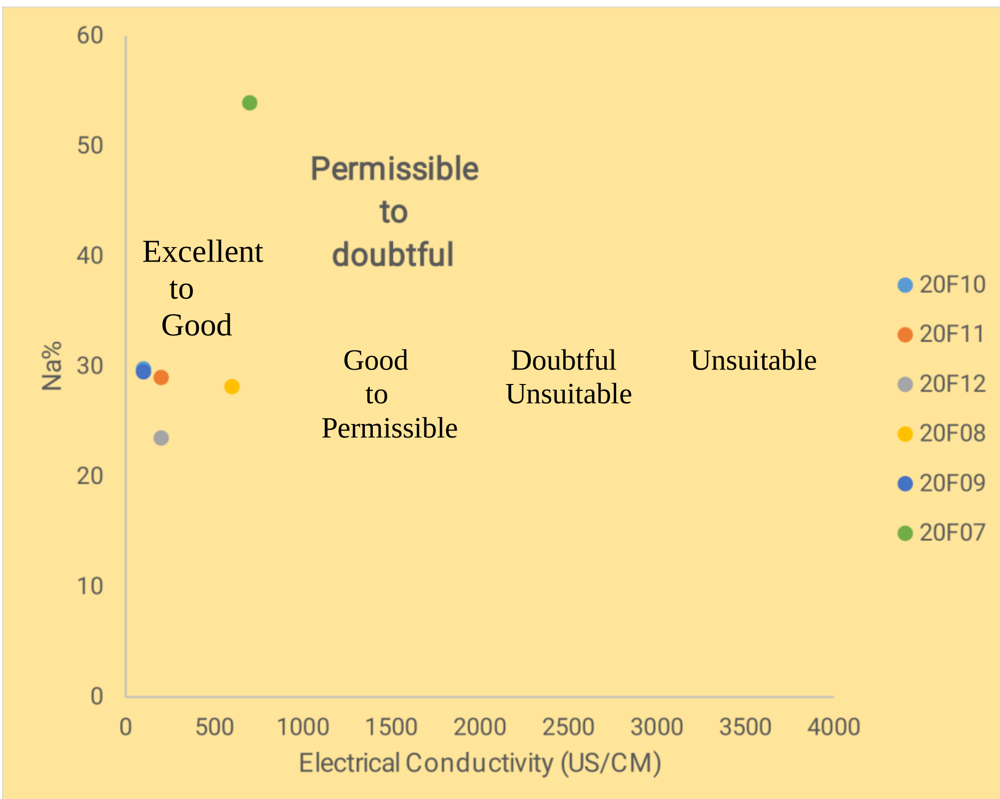

Figure 10. Wilcox Diagram of Ijokodo Stream Samples

3.4.3 Irrigation Water Quality Parameter

Irrigation water quality the suitability of groundwater for irrigation is conditional on the effects of mineral constituents of water on both the plant and soil (Ayers, 1985; Doneen, 1964). Excessive number of dissolved ions in irrigation water affects plants and agricultural soil physically and chemically, thus reducing the productivity. Agriculture and related labor are the main occupation of the rural people in the Başköy plain (Kolo, 2007). Therefore, the determination of irrigation water quality in the plain is gaining importance. So, various classifications (EC, TDS, Na%,MR, and KR) have been made to determine the irrigation water quality for springs in dry and rainy periods. Allowable limits of the irrigation water quality parameters are given as water class in Table 10.

Table 10
Summary statistics of physical, chemical, and pollution parameters of the Ijokodo Stream Samples

Parameter	Units	Minimum	Maximum	Average	WHO (2011)
In situ measurements					
pH		1.7	8.3	5.0	6.5–8.8
Temp.	^oC	25	32	28.50	
EC	µS/cm	100	800	450	
TDS	mg/L	170	560	365	600–1000
Major Elements					
Na^+	meq/L	23.51	53.93	38.72	
Ca^{2+}	meq/L	25.66	37.42	31.54	
K^+	meq/L	6.65	26.6	16.63	
Mg^{2+}	meq/L	6.74	9.15	7.95	
Criterions of irrigation					
Na%	%	0.48	0.64	0.56	
MR	meq/L	17	24	21	
KR	meq/L	0.71	1.19	0.95	

3.4.4 Electrical conductivity (EC)

According to the Food and Agriculture Organization (Ayers and Westcot, 1985) irrigation water quality guidelines, electrical conductivity allowable limit value should be from <700 to 30,000 μS/cm. The EC values of Ijokodo Stream range from 100 to 800 μS/cm with an average value of 450 μS/cm (Table 10). Also, according to EC, 100% of the stream samples are suitable for irrigation.

3.4.5 Total Dissolved Solids (TDS)

To ascertain the suitability of groundwater for any purposes, it is essential to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Catroll 1962; Freeze and Cherry 1979). In the FAO irrigation water quality guidelines (Ayers and Westcot 1985), TDS allowable limit value should be from <500 to 30,000 mg/L. TDS values of stream samples were measured in situ in this study. The TDS values in the study area vary from 170 to 560 mg/L with an average value of 365 mg/L (Table 10). Also, according to TDS classification, 100% of the Ijokodo stream samples are suitable for irrigation. (Catroll 1962; Freeze and Cherry 1979, Table 10).

3.4.6 Sodium percentage (Na%)

Sodium concentration plays an important role in evaluating the groundwater quality for irrigation because sodium causes an increase in the hardness of soil as well as a reduction in its permeability (Tijani, 1994; Karanth 1989; Mohan *et al.*, 2000). The Na% values range from 0.48 to 0.64 % with an average value of 0.56% (Table 10). Also, according to the relating sodium percentage and total concentration (Wilcox, 1955), the Ijokodo Stream samples are excellent to good and the stream samples are suitable for irrigation.

3.4.7 Kelly's ratio

The KR of unity 1 is indicative of good quality of water for irrigation. Kelley (1963) suggested that this ratio for irrigation water should not exceed 1.0. Average KR was found in the range from 0.71 to 1.19 meq/L in Ijokodo stream samples (Table 10). All stream waters are suitable^ for KR < 1 meq/L for irrigation in the investigation area, except stream sample 20F07.

3.4.8 Magnesium Ratio

MR is identified as magnesium hazard (MH) and magnesium adsorption ratio (MAR). Paliwal (1972) introduced an important ratio called index of MH. Also, MR of irrigation water is proposed by Szabolcs and Darab (1964) and refined by Raghunath (1987). The MR values exceeding 50 meq/L is considered harmful and unsuitable for irrigation use. When the value is <50 meq/L, groundwater is suitable for irrigation. Average MR was found in the range from 17 to 24 meq/L (Table 10) in the stream samples, and these stream waters are suitable due to MR < 50 meq/L for irrigation in the study area.

CONCLUSIONS

The results of the physicochemical and the hydrochemical studies show that the Ijokodo stream is slightly alkaline. The trace metals show varied average results in the streams samples of the study area. On the average, the respective values of the trace metals and major metals are generally below the World Health Organisation (WHO) standard for potable water. Results of AF (<1) show that the Ijokodo streams have not been heavily contaminated. The estimated results of geo-accumulation (<0) also confirmed this. The computed values of SAR on the average indicated that the water phase of the Ijokodo streams contain a slight low sodium hazard of 9.5 and this may not be potentially hazardous for irrigation practices. The Gibb's diagrams suggest that, chemical weathering of the rock forming minerals is the main process which contributes the ions concentration in the water while, The Wilcox diagram result reveals that all water samples are within the area of excellent to good except for sample 20F07 (Permissible to Doubtful), thus, all the water samples can be used for irrigation. However, if the anthropogenic discharge of wastes into the streams (tributaries) is not checked, the concentration of toxic metals in the water phase will increase abnormally overtime and this will endanger the growth of plants, the health of aquatic organisms and finally man that feed on the aquatic animals. Nevertheless, based on the averages of all the analyses carried out, the stream may be regarded as potable for drinking and for domestic usage and not applicable for irrigation purposes prescription of necessary treatment measures since the lake is a source of water supply in the area.

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