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Physico-Chemical Evaluation and Groundwater Quality Studies in Itapaji Ekiti and Its Environs, Southwestern Nigeria

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Abstract: *Water resource for drinking purpose has suspiciously become unsafe in some parts of Ekiti State, Southwestern Nigeria. The various water sources are been consumed with inadequate knowledge of their suitability as regards the various point and non-point sources of contamination in the area. This study is therefore aimed at evaluating the hydrochemical concentrations and determine the quality of the various water sources in the study area. Field in-situ parameters such as pH, temperature and electrical conductivity were determined and a total of 35 water samples were taken for the determination of the concentration of major ions present in the various water sources in the study area (Iye, Itapaji and Omu-Titun). The concentration of the physical and chemical parameters are compared to World Health Organisation Standard for suitable drinking water. The temperature, pH, electrical conductivity and TDS ranges from 17°C to 29°C, 5.7 to 7.8, 20 to 1130ms/cm and 15 to 740mg/l respectively. Nearly all the water samples have the physico-chemical parameters fall within the permissible limits except W31 with pH, Ec and TDS, Mg^{2+} and Cl^- above the set limits. The dominance of the cations for the water samples are in the order of $Na^++K^+>Ca^{2+}> Mg^{2+}$ while the order of dominance for anions follows $HCO_3^-+CO_3^{2-}> Cl^-> SO_4^{2-}$. Also, the Gibb's plot indicated that the main source of the ions in the water could be attributed to the intense rock weathering activity in the area which upshot into two main hydrochemical facies which are ($Ca(Mg)HCO_3$ and ($Ca(Mg)Cl(SO_4)$) facie types. The presence of calcium and magnesium in desirable quantity indicated that most of the water sources are good and suitable for drinking.*

Keywords*: Groundwater, Hydrochemical facie, Water quality, Itapaji, Ekiti State*

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I. Introduction

Water is life, and life tends not to exist if there is no water. Water is greatly essential to keep human life, animal and plant flourish.[1] The sources of water for any specific purpose are not as important as its suitability for the desired purpose.[2] Accessibility to portable and safe drinking water is a fundamental right of human but much of the world's population does not have access to quality water. The availability of good quality water is an indispensable feature for preventing disease and improving quality of life.[3] Water chemistry depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water-rock interaction.[4] The quality of groundwater reflects input from the atmosphere, the water-rock-sediment-soil interactions as well as from anthropogenic contaminant sources.

The menance of water borne diseases and epidemics is still on the high at the horizon of developing countries.[5] More than 1 billion out of about 6 billion people on earth lack access to safe drinking water.[6] WHO[7] also reported that inadequacy of access to sanitation and lack of quality water affects more than 40% of the world population due to political, economic and climatological reasons. The recent report said about 80% of all human diseases are caused by water.[8] They estimated further in their report that 2.6 billion people across the globe lack access to improved sanitation facilities with the consequent of direct or remote negative impact on the natural water bodies' quality.

In Nigeria today, research indicates that, majority of the common fresh water sources are polluted, resulting to serious and severe outbreak of various diseases. Some previous investigations indicated that 19% of the whole Nigerian population is affected, with some communities having up to 50% incidence.[9] This menance has raised serious concerns to World Health Organisation in recent times, in an attempt to improve cultural and socio-economic standards of people in the tropical region. These diseases continue to be major source of human mortality and morbidity.[10] The suspected outbreak of cholera in the region of the study area motivated this study. Hence, this study is aimed at evaluating the hydrochemistry of groundwater in the study area and determine the quality of the various water sources for drinking purpose as well as revealing the factors controlling the distribution and concentration of elements in the water bodies. The hydrochemical constituent of each water point is compared with the standard of World Health Organisation.

II. Location and Accessibility of the Study Area

The study area fall in part of Ekiti State, Southwestern Nigeria. The study area include towns such as Iye, Itapaji and Omu-Titun. It falls within the basement complex terrain of southwestern Nigeria with latitudes 7° 53' to 8° 05'N and longitudes 5° 23' to 5° 30'E [Figure 1]. The area is a rocky environment with average elevation of 240m above sea level. The area has tropical climate characterized by high humidity [60 – 80%] and mean annual rainfall of 1500mm. Two prominent seasons occur in the area with a long rainy season of March to November and short dry season commencing towards ending of November and terminating in early March.

Geologically, the study area is dominated by crystalline rocks (igneous and metamorphic) which belong to part of the Precambrian basement rocks of Southwestern Nigeria. The geological appraisal of the area revealed that the main lithological units include migmatite gneiss, granite gneiss, older granite, and charnockites.[11]

III. Materials and Methods

Samples from both wells and boreholes were collected from the study areas for laboratory analysis. A total of 35 water samples were taken, as indicated in figure 1, for the determination of the concentration of major ions (anions and cations) present in the water samples. All samples were collected in 2litres preconditioned polyethylene bottles. They were initially rinsed with 10% nitric acid and followed by 3-4 time rinsing with distilled water to ensure that the sample bottles were free from any impurities. Samples collection, preservation and treatment were done according to standard methods.[12]

At each sampling location, field in-situ parameters such as pH, temperature and electrical conductivity were determined. Thereafter, samples were collected into the polyethylene bottles in duplicate and well-labelled for cation and anion analysis. The samples for cation analysis were acidified with concentrated nitric acid and kept in an ice chest prior to laboratory analysis.

IV. Results and Discussion

1. PHYSICO-CHEMICAL EVALUATION

Based on the interest of this research, the composition of the water samples is classified based on main ions such as sulphate, chloride, carbonate, bicarbonate ions (main anions) and also potassium, sodium, magnesium and calcium ions (main cations). Also, the electrical conductance, total hardness, Total dissolved Solids among other are put into consideration. The hydrochemical result for the parameters analysed as well as the statistical data are presented in Table 1 and 2 respectively. The concentration of the physical and chemical parameters are compared to World Health Organisation (2011) Standard as given in Table 2.

It is important to note that the temperature values are known to be dependent on the climatic condition at a particular geographical area and period. Though, there is no standard for temperature for the purpose of drinking or irrigation, but has great influence in water-rock interaction. The temperature of water sources in the study area ranges from 17^oC to 29^oC with mean value of 24.6^oC. Therefore, the temperature values for the water samples are considerably normal because it falls within values near the room temperature. Other physical parameters determined include pH, electrical conductance, total Alkalinity, total dissolved solids and total hardness, which all falls within the permissible limits as prescribed by WHO except for W31 with pH, Ec and TDS values of 5.7, 1130µcm/s and 1240mg/l respectively.

The anionic and cationic concentration of the samples were also evaluated for drinking purpose. The anionic concentration for all the samples are within the acceptable limits except for W31 with concentration of Cl^- to be 291.79mg/l. Also, the only notable excessive cationic concentration is recorded in the concentration of Mg^{2+} in sample W31 with the value of 364.0 as compared to set limits of 150mg/l by WHO.

2. Water Quality Evaluation

2.1 Stiff Plots: From the stiff pattern as shown in Figure 2, the order of dominance for the cations and the anions are Na^++K^+>Ca^{2+}> Mg^{2+} and HCO_3^-+CO_3^{2-}> Cl^-> SO_4^{2-} respectively. The patterns are largest at W13, W31 and W32 indicating high concentration, though, still within the permissible limits for drinking.

2.2 Piper's diagrams: The diagram consist of diamond-shaped fields which is used to represent the composition (hydrochemical facies) of the water samples for each location. As shown in figure 3, four hydrochemical facies were identified in the study area. They include; P-field (Na(K)Cl(SO_4) facie type which accounts for 9% of dominance, the I-field (Ca + Mg facie type) representing 8% dominance of the water samples, the M-field (Ca(Mg)HCO_3 facie type) with 34% of dominance while the most dominant facie is the N-field (ca(Mg)Cl(SO_4) facie type) with 49% of dominance. It is apparent that only W31 plotted in the upper part of the N-field indicating an area of permanent hardness.

2.3 Gibbs Diagram: The ratio of $(Na^+ + K^+)/(Na^+ + Ca^{2+})$ against TDS for the cations and $Cl^-/Cl^- + HCO_3^-$ against TDS for the anions (Figure 4) were plotted (Gibb's diagram) which indicated that all the dissolved ions plotted in the region of rock dominance. This suggests that the dissolved ions in the water sources are formed essentially from the surrounding rock lithology through the process of leaching.

V. Figures And Tables

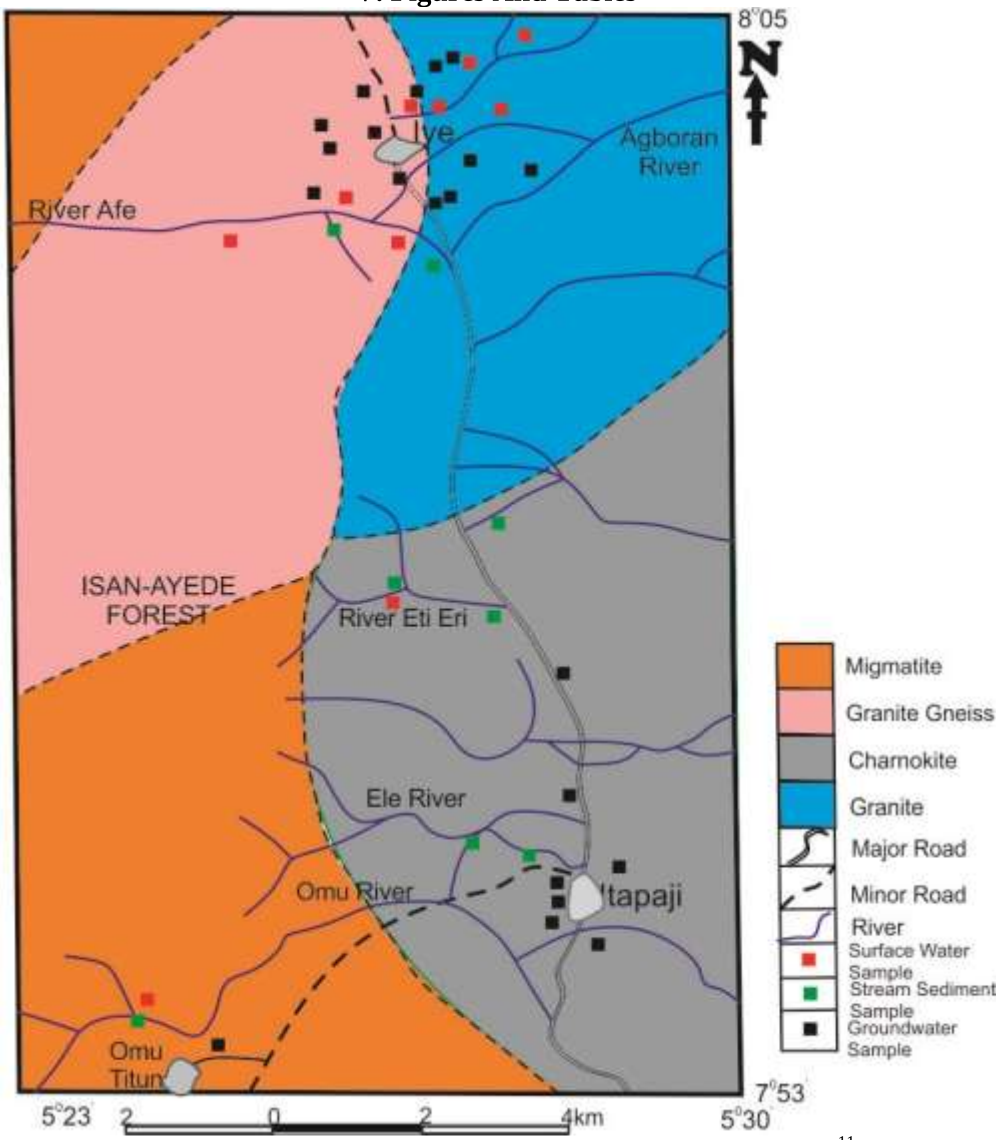

Fig. 1: Geological map of the area indicating the sampling points.[11]

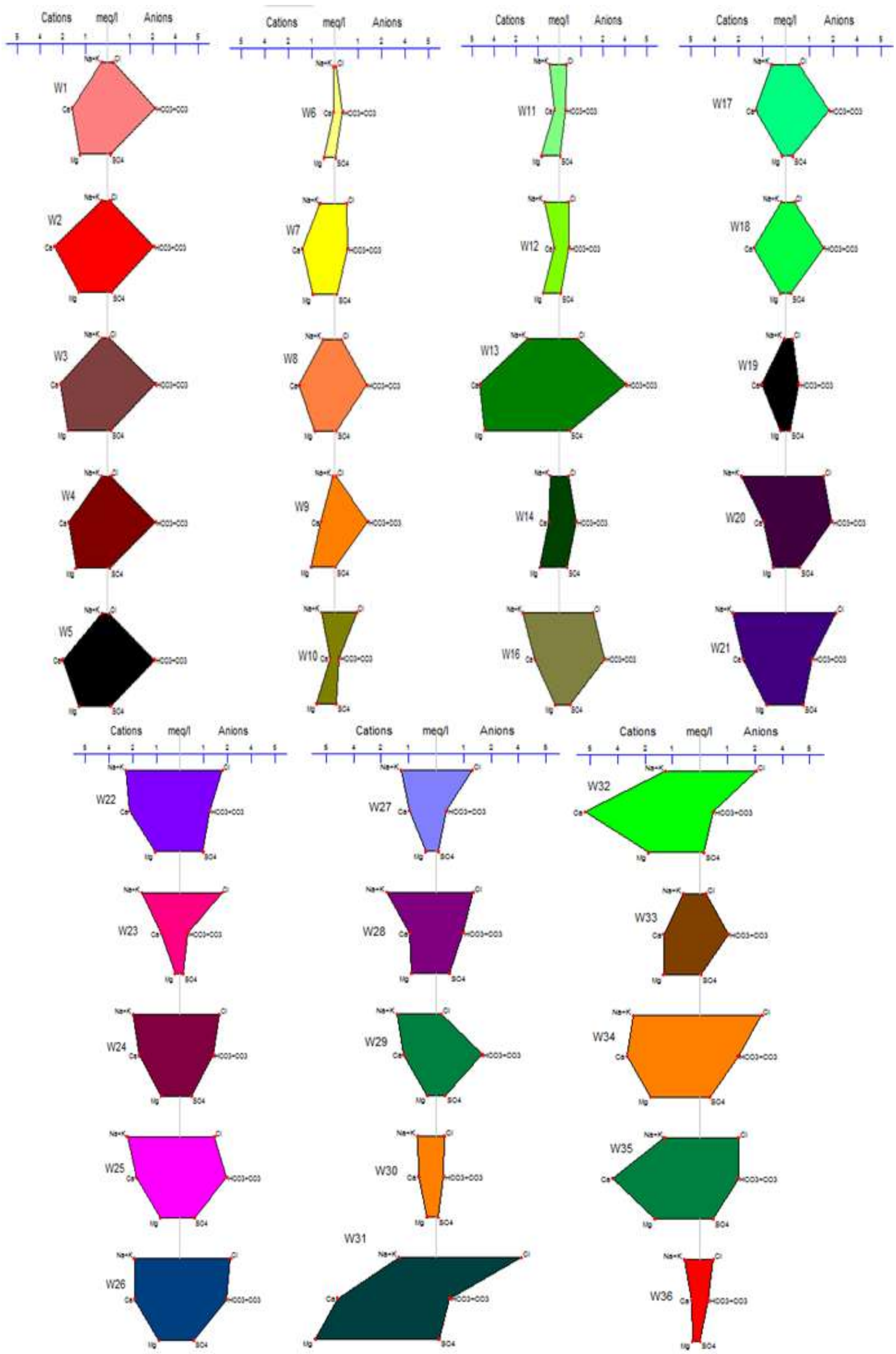

Figure 2: A Stiff Diagram showing the dominant Cation/Anion in the analyzed water samples.[13]

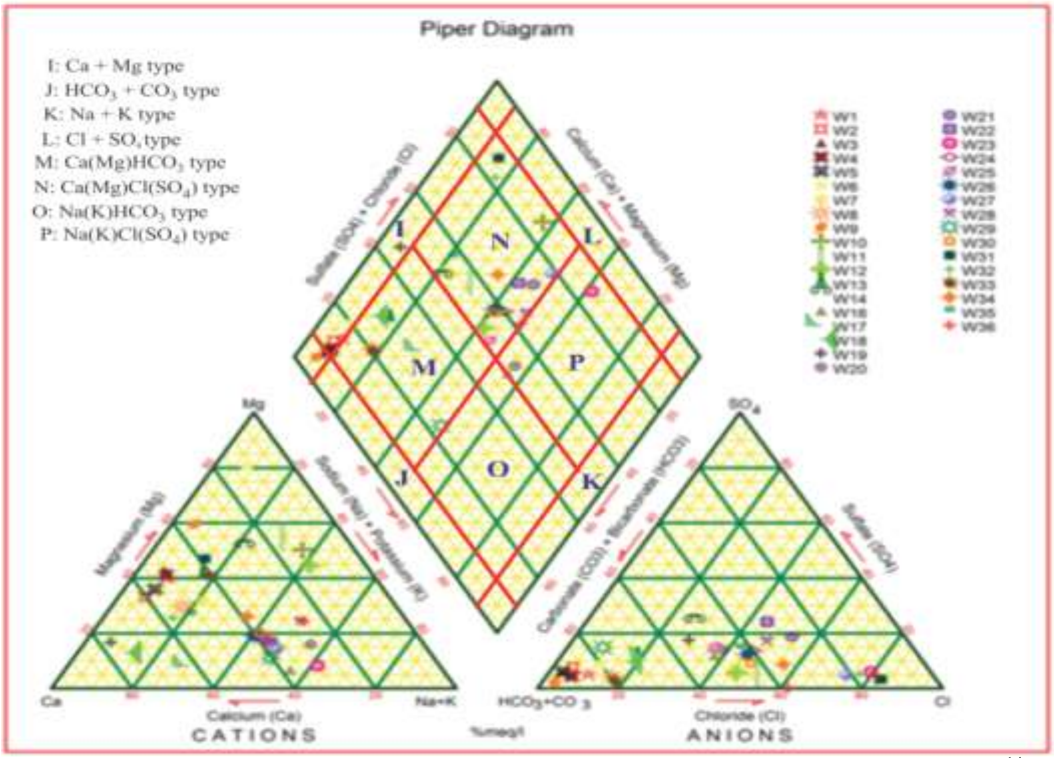

Figure 3: Pipers diagram showing the hydrochemical facies of the analyzed water samples.[14]

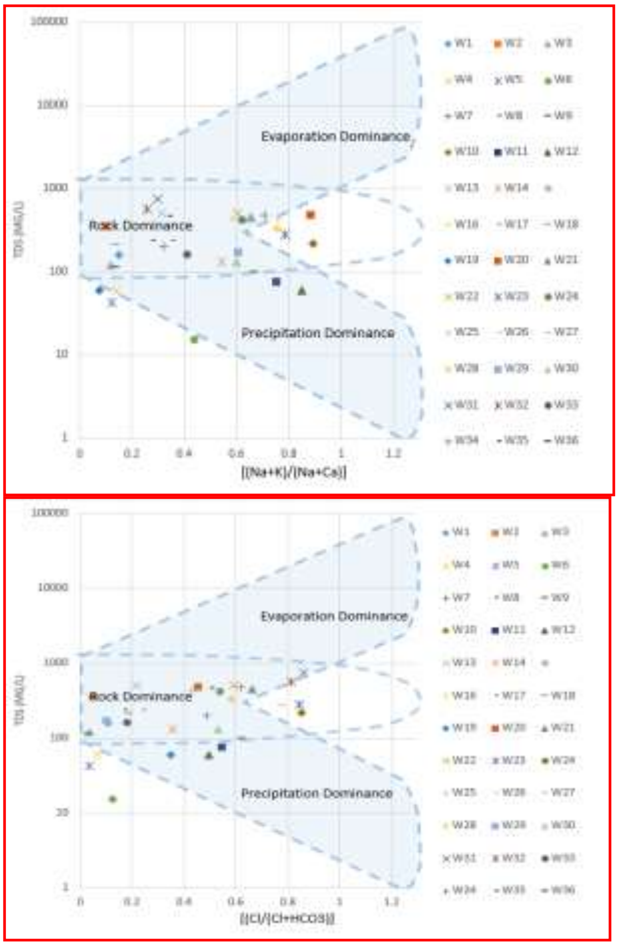

Figure 4: Gibbs Plot showing the origin of dissolved ions in the analyzed water samples.[15]

Table 1: Result for the physicochemical parameters of the Water Samples

S/N	**ID**	**pH**	**Ec (µs/cm)**	**TDS (mg/l)**	**TA (mg/l)**	**TH (mg/l)**	**NO_3 (mg/l)**	**SO4 (mg/l)**	**HCO_3 (mg/l)**	**Cl (mg/l)**	**Ca (mg/l)**	**Mg (mg/l)**	**Na (mg/l)**	**K (mg/l)**
1	W1	7.2	450	1	257	160	1.5	7	154.1	10.7	38.4	18	5.8	2.9
2	W2	6.8	600	2	311	220	1	10.5	149	4.8	56.8	18.9	5.6	2.9
3	W3	6.8	550	5	350	232	1.8	8	155.1	3.1	50.4	25.8	5.7	3.2
4	W4	6.9	550	7	273	215	0.9	6	155	6.3	42	20.6	5.8	2.7
5	W5	7.2	550	11	297	198	0.8	7.9	151.4	3.1	48.4	18.7	5.8	2.8
6	W6	N/D	20	15	N/D	N/D	N/D	2	24	1.99	1.6	6.86	1.12	0.31
7	W7	N/D	300	200	N/D	N/D	N/D	5	40	21.92	33.6	13.73	16.25	2.19
8	W8	N/D	360	240	N/D	N/D	N/D	4	100	11.95	36.79	12.58	9.16	8.55
9	W9	N/D	170	115	N/D	N/D	N/D	2	104	1.99	14.41	14.87	2.19	0.66
10	W10	N/D	320	215	N/D	N/D	N/D	3	12	39.85	4.8	11.44	12.22	6.18
11	W11	N/D	110	75	N/D	N/D	N/D	2	20	13.95	5.61	12.01	9.91	4.11
12	W12	N/D	90	60	N/D	N/D	N/D	3	32	17.93	5.59	10.87	16.15	5.13
13	W13	N/D	760	505	N/D	N/D	N/D	28	224	35.86	88	50.34	29.01	20.15
14	W14	N/D	190	130	N/D	N/D	N/D	20	56	17.93	12.01	13.16	7.16	7.25
15	W16	N/D	650	430	N/D	N/D	N/D	28	151.3	65.8	27.3	2.9	29.8	28.1
16	W17	N/D	360	240	N/D	N/D	N/D	17	131.8	23.9	30.5	2.4	12.6	7.1
17	W18	N/D	310	210	N/D	N/D	N/D	12	117.1	15.9	32.3	3.4	4.6	2.1
18	W19	N/D	90	60	N/D	N/D	N/D	10	39	12	25	3.3	2.1	0.4
19	W20	7.4	720	480	N/D	N/D	N/D	33	141.5	67.7	22.5	7.8	32.8	32.3
20	W21	6.1	820	450	80	163	N/D	42.5	80	89.34	43.61	12.04	44.46	29.52
21	W22	6.8	900	17	92	188	0.0	56.1	92	76.34	51.24	15.36	46.8	28.7
22	W23	6.5	520	280	24	67	N/D	7.65	24	75	19.08	3.18	35.1	16.4
23	W24	6.5	750	410	104	134	N/D	28.05	104	70.38	41.97	11.81	39.78	25.42
24	W25	6.8	780	430	144	162	N/D	34.85	144	62.05	44.76	12.08	42.9	31.98
25	W26	7.1	750	65	144	170	0.0	33.15	144	90.64	46.34	13.12	39	24.6
26	W27	6.9	500	50	28	68	0.0	5.1	28	56.13	23.44	5.58	27.3	13.53
27	W28	7.0	610	60	72	97	0.0	28.05	72	57.76	22.9	12.92	39.02	17.42
28	W29	7.0	320	60	92	82	0.0	18.7	122	8.15	28.34	4.68	31.98	12.3
29	W30	5.7	250	50	20	58	0.0	3.4	20	13.11	15.26	4.82	14.04	8.2
30	W31	7.3	1130	740	36	440	N/D	7	36.72	131.79	86.4	64.06	26.25	18.63
31	W32	7.6	860	560	34	348	N/D	8	34.68	86.89	100.8	27.46	19.11	26.73
32	W33	7.6	240	160	74	148	N/D	2	75.48	9.76	32	19.45	3.78	21.87
33	W34	7.8	740	480	100	252	N/D	20	102	95.65	64	26.31	22.05	76.95
34	W35	7.0	700	460	100	276	N/D	28	102	59.56	76.8	24.02	16.8	32.4
35	W36	5.8	210	55	22	36	0.0	0.1	22	20.83	7.09	4.07	15.6	0.41

Table 2: Statistical Data Compared with NSDWQ and WHO Standards for the Physicochemical parameters of the Water Samples.

Parameters	**Present Study** M/in.	Max.	**Mean**	**WHO (2011)**
pH	5.7	7.83	5.7-7.83	6.5 - 8.5
EC (µs/cm)	20	1130	492.3	1000
TDS (mg/l)	15	740	273.9	1000
TA (mg/l)	20	350	125.5	350
TH (mg/l)	36	440	176.9	440
NO_3 (mg/l)	0.8	1.8	1	1.8
SO_4^{2-} (mg/l)	0.1	56.1	56	56.1
HCO_3^-(mg/l)	12	224	212	NE
Cl^- (mg/l)	1.99	131.8	129.8	200
Ca^{2+} (mg/l)	1.6	100.8	99.2	200
Mg^{2+} (mg/l)	2.4	64.1	61.66	150
Na^+ (mg/l)	1.12	46.8	45.68	500
K^+ (mg/l)	0.31	76.9	76.64	NE

VI. Conclusion

The physico-chemical appraisal of the various water samples revealed that the water sources are mostly within the permissible limits of WHO and NSDWQ standards for drinking and irrigation purposes. The Stiff patterns revealed the variations of the dominance of the chemical parameters is in the order of Ca^{2+}> Mg^{2+}, Na^++K^+ and HCO_3^-+CO_3^{2-}> Cl^-> SO_4^{2-} for cations and anions respectively. The Piper diagram indicated two main hydrochemical facies which are ($Ca(Mg)HCO_3$ and ($Ca(Mg)Cl(SO_4)$) facie types. Furthermore, the water type found in the study area are concentrated with magnesium and calcium which made the water sources to be good for drinking purpose. The presence of Ca in the water samples from the study area is good for human bone development. The Gibbs' diagrams suggest that chemical concentration of the water samples are sourced to be from the chemical weathering of the rock forming minerals in the area.

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