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HydroGeochemical Analysis of Groundwater in Part of Igbo-Ora South Western Nigeria

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ABSTRACT

This study is aimed at analyzing the hydrogeochemistry of groundwater in part of igbo-ora, South Western, Nigeria. A total of 21 representative samples was collected from 20 hand dug wells and 1 borehole. In situ parameters like Ph, Electrical conductivity (Ec) were measured. Major cations and some anions were subsequently determined in the laboratory using AAS for metal analysis, spectrometric determination of chloride, UV- visible screening method for nitrate determination, vanado- molybdo phosphoric acid, colorimetric method of phosphate determination and turbidimetric determination of sulphate. The suitability of these water samples was evaluated by subjecting the results to statistical analysis. Statistical summary of geochemical data shows mean metal contents of chemical parameters determined to be Ec (997.5), Ph (10.605), Cd (0.0179), Pb(0.000991), Fe(0.0409), Zn(0.2149),Cr(0.097), Cu(0.1405), Mn(0.0829), Na(0.1912), Mg(2.0747), K(1.6306), Cl(18.08), Ni(1.7073), $P0_4^{3-}$(1.5438) and So_4^{2-}(26.4241). The order of element with lower value are Cd<(Pb, Fe)<K<Mn<Cr<Cu<Mg<Zn<Na<P_{04}<Ca<Ni<Cl< S_{04} and the order of element with highest value are Cd<Pb<Fe<Mn<Cr<Mg<Cu<Na<Zn<P_{04}<K<Ni<Ca<C<S_{04}.The trend of the elements across individual element.shows that Sulphate (So_4), Cl and Ph are with values above 5 and the remaining chemical parameters are from 0-5. By using frequency distribution plots it could be observed that all the chemical parameters are asymmetrical and positively skewed. The T-test correlation analysis was done for the chemical/parameter studied. The result of the analysis was presented in form of statistical table showing the level of correlation between the chemical parameters sampled using Eviews 9 statistics software package. It can be concluded that all the heavy metals, anions and cations, and other chemical parameters are far lower than the WHO acceptable standard for drinking water.

Keywords: Hydrogeochemistry, Parameters, Metal Analysis, Spectrometric Determination, Statistical Analysis

I. INTRODUCTION

As far as Nigeria is concerned, there is abundant of surface and groundwater resources, particularly in the South- Western region which is entirely within the tropical rainforest zone. [1] The major cations found in groundwater include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and anions such as bicarbonate (HCO_3^-), sulphates (SO_4^{2-}), chloride (Cl^-) with non-ionic constituents like oxides, phenols, synthetic detergents, dissolved gases e.g. oxygen (O_2) and carbon dioxide (CO_2). [2] Groundwater contains dissolved minerals from the soil layers through which it passes. [3] Trace elements in groundwater are defined as chemical elements dissolved in water in minute quantities, always or almost always in concentration of less than 1 mg of trace element in one liter of water. [4] Hydrogeochemical character of groundwater and groundwater quality in different aquifers over space and time have proven to be important in solving problems of groundwater management. [5; 6; 7; 8] Similar studies were done by [9; 10; 11; 12; 13; 14] Therefore the primary aims and objectives of this study are to determine the Hydrogeochemical analysis of groundwater in part of Igbo-ora Ibarapa, Oyo state south western Nigeria, Statistically analysed the results of hydrochemistry of the ground water of the area and Interpretation of statistical analysis of the results

Location Area and Accessibility: Igbo Ora which is the study area falls within latitudes 70.15'N and 70.55' N and longitudes 30′E and 30.30'E. It is located approximately 100 Km north of the coast of Lagos and about 95 Km west of the Oyo state capital and neighboring city of Ibadan. The predominant occupation of the people is farming. Fig. 1. The climate is tropical continental: rainfall (with double maxima) is about 1,600 mm on the average; and the temperature is usually about 27°C on the average too. Relative Humidity is high. It is not less than 80% on the average. The vegetation is purely Guinea Savanna with tall grasses and stuntedly grown trees of thick barks. The area is partly lowland and undulating and the town (Igboora) is traversed by Agogo stream. There are number of ponds and swamps from where the inhabitants draw water at their seasons, they all have water mainly during rainy seasons and the swamps produce little spring in only season. [15] The drainage pattern is dendritic in nature that joins to the river oyan that flows through the area. This is an indication that the rock which underlained the area are resistance to erosion streams is the major source of water supply to mostly all the residents while groundwater from hand dug wells from a major source for domestic and other uses.

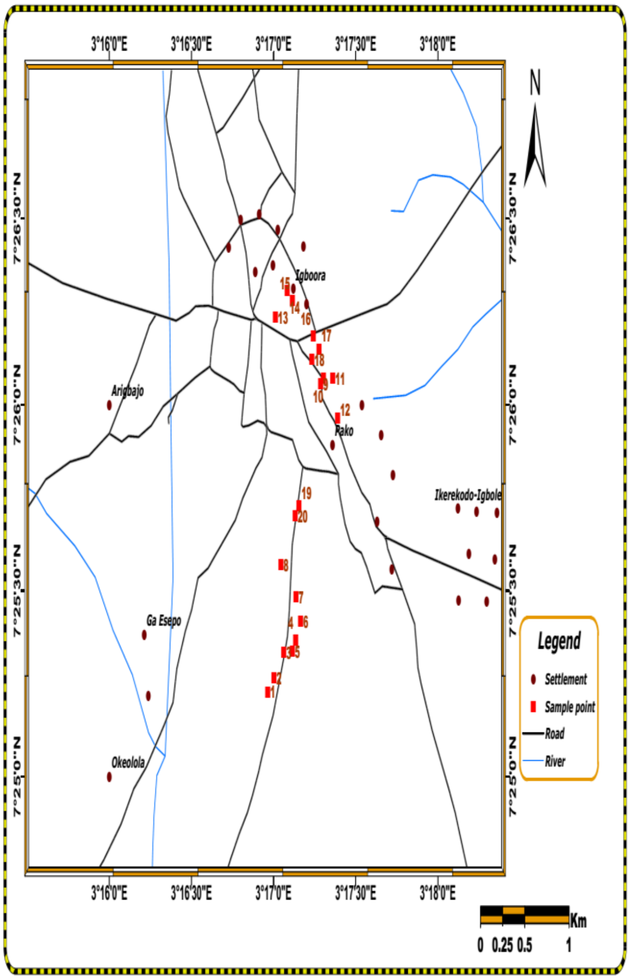

Figure 1: Map showing location and accessibility of the study area

Geologically the area is underlain by Precambrian rocks of Nigeria which has been described by various authors such as [16; 17]. The major rock types found in the area are banded gneiss, granitic gneiss, quartz-mica, schist and pegmatite. The rocks are highly weathered and fractured in most places; the basement complex geology proves further that there were five major rock types of Precambrian age which were recognized. Fig. 2

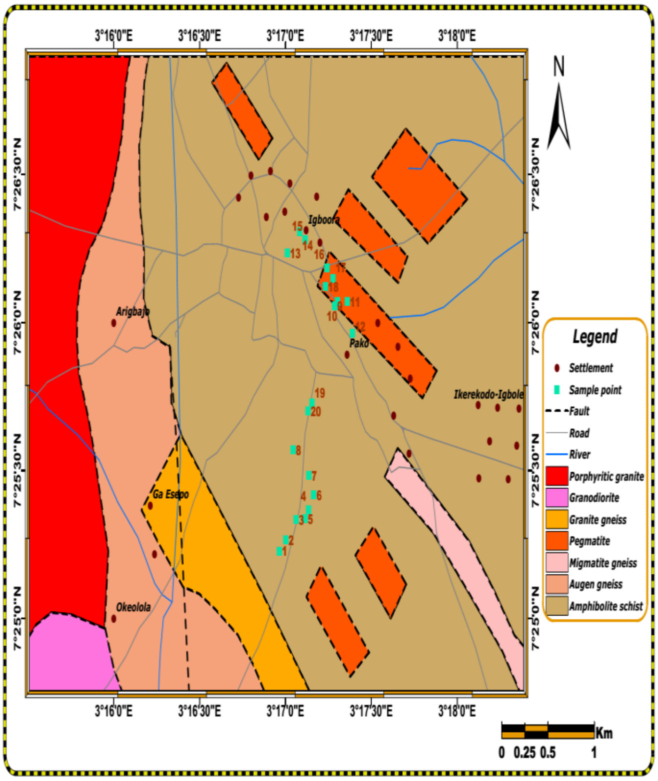

Figure 2: Map showing the geology of the study area.

II. METHODOLOGY

A systematic field work was carried out during which a total of 21 water samples were collected directly from hand dug wells. The coordinates of the wells was taken using Garmin Handheld GPS which was used to determine the x, y coordinates of each water sample point. Sterilized bottled water was used to take water sample and the bottle were sealed, labeled and sent to Obafemi Awolowo University Research laboratory for further analysis. Atomic absorption spectrometric technique was used for the analysis. For the correlation between chemical parameters a Pearson T-test analysis was used using N-2, where N is the number of water sampled. The r statistics for the 1% (99%) confidence level from the Pearson T-test table was 0.549 and 0.503 for 2% (98%). This value was used to determine if correlation exist between one parameter to the other (table 4).

Statistical Analysis: EVIEWS statistics software package (9 version) was used for the statistical analysis of this study. All data sampled were tested for correlation analysis to determine associations that exist among various parameters measured for the study. The Pearson 'r' statistics analysis showed coefficient of their correlation and the confidence of their significance. Correlation coefficient is a common tool used to assess the relationship between two variables and how well one predicts the other. [18] Therefore, the results of the chemical analysis were subjected to statistical analysis.

III. INTERPRETATION AND DISCUSSION OF RESULT

Statistical summary of geochemical data (Table 2) shows mean metal contents of chemical parameters determined from samples. Ec (997.5), Ph (10.605), Cd (0.0179), Pb(0.000991), Fe(0.0409), Zn(0.2149),Cr(0.097), Cu(0.1405), Mn(0.0829), Na(0.1912), Mg(2.0747), K(1.6306), Cl(18.08), Ni(1.7073), $P0_4^{3-}$(1.5438) and So_4^{2-}(26.4241). Maximum and minimum value was also recorded for each element. There is no evidence of mining or industrial activities within the vicinity of the study area. Hence, the only controlling factor contributing to the distribution of elemental concentration is the surface geology.

TABLE 1: Summary of the Result of Hydrogeochemical Analysis

well no	location	EC	Ph	Cd	Pb	Fe	Zn	Cr	Cu	Mn	Na	Mg	Ca	K	Cl	Ni	PO_4	SO_4
1	IGB 01	1129.1	12.1	0.023	0.012	0.048	0.227	0.092	0.088	0.061	0.138	0.102	1.425	1.201	22.347	1.673	1.306	24.977
2	IGB 02	1037.2	12.7	0.028	0.013	0.038	0.251	0.088	0.087	0.066	0.137	0.097	0.637	1.765	23.725	1.481	1.159	20.004
3	IGB 03	1092.3	11.8	0.021	0.012	0.064	0.186	0.101	0.081	0.054	0.141	0.103	1.312	2.315	17.703	1.574	1.63	25.58
4	IGB 04	953.5	10.4	0.016	0.015	0.045	0.224	0.122	0.099	0.072	0.159	0.11	1.065	1.596	22.365	1.778	1.388	22.277
5	IGB 05	953.8	10.6	0.025	0.007	0.044	0.225	0.121	0.092	0.077	0.152	0.098	2.038	1.979	23.204	1.074	0.665	24.568
6	1GB 06	920.6	11.7	0.018	0.015	0.069	0.199	0.118	0.09	0.081	0.21	0.11	1.179	0.922	16.823	1.243	0.617	24.981
7	IGB 07	836.2	11.7	0.031	0.011	0.032	0.2	0.11	0.091	0.09	0.211	0.1	1.32	2.813	18.89	2.214	1.73	25.998
8	IGB 08	1103.6	10.2	0.017	0.009	0.039	0.233	0.108	0.133	0.054	0.133	0.107	1.443	2.925	23.919	3.243	2.547	29.533
9	IGB 09	893.4	10.2	0.022	0.009	0.073	0.144	0.112	0.155	0.059	0.155	0.12	1.578	1.231	21.192	1.97	2.621	31.33
10	IGB 10	820.8	8.6	0.025	0.006	0.042	0.182	0.115	0.171	0.062	0.171	0.129	2.312	1.38	9.815	1.628	2.49	32.624
11	IGB 11	864.3	9.1	0.02	0.006	0.038	0.271	0.089	0.162	0.093	0.192	0.159	1.818	2.384	19.505	1.76	1.284	27.939
12	IGB 12	754.4	9.5	0.024	0.008	0.068	0.233	0.077	0.163	0.099	0.203	0.154	2.05	0.969	19.506	2.25	1.668	24.797
13	IGB 13	754.7	9.8	0.016	0.005	0.033	0.188	0.091	0.174	0.091	0.214	0.161	2.166	1.118	22.165	1.534	1.279	23.853
14	IGB 14	728.5	10.2	0.016	0.01	0.029	0.288	0.078	0.14	0.1	0.23	0.146	2.563	1.609	16.004	1.065	0.758	22.935
15	IGB 15	692.1	9.3	0.02	0.01	0.056	0.255	0.084	0.155	0.101	0.195	0.187	2.465	2.818	14.976	1.119	0.733	25.213
16	IGB 16	697.9	10.4	0.013	0.01	0.025	0.241	0.08	0.179	0.097	0.279	0.163	3.732	1.314	12.336	1.102	1.279	30.211
17	IGB 17	1467.8	11.4	0.009	0.008	0.022	0.21	0.073	0.178	0.11	0.278	0.167	4.624	1.835	18.278	1.743	1.365	31.093
18	IGB 18	1348.3	10.8	0.01	0.01	0.038	0.178	0.093	0.181	0.103	0.281	0.15	2.7	1.852	17.085	1.642	1.271	26.599
19	IGB 19	1419.9	11.4	0.009	0.009	0.023	0.173	0.091	0.2	0.108	0.2	0.142	3.076	1.114	12.484	2.476	1.932	35.553
20	IGB 20	1239.5	11.3	0.011	0.011	0.027	0.233	0.106	0.151	0.09	0.221	0.143	3.145	1.072	12.303	1.541	2.376	22.823
21	IGB 21	1239.9	9.5	0.002	0.012	0.005	0.171	0.093	0.18	0.074	0.115	0.12	0.921	0.031	15.055	1.743	2.323	22.019

TABLE 2: Mean, Median, Mode, Standard Deviation, Range, Minimum, Maximum and Percentile of the results

		Ec	Ph	Cd	Pb	Fe	Zn	Cr	Cu	Mn	Na	Mg	Ca	K	Cl	Ni	PO_4	SO_4
N	Valid	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean		997.514	10.605	.018	.010	.041	.215	.097	.140	.083	.191	.132	2.075	1.631	18.080	1.707	1.544	26.424
Median		953.500	10.400	.018	.010	.038	.224	.093	.155	.090	.195	.129	2.038	1.596	18.278	1.642	1.365	25.213
Mode		692.100[a]	10.200	.016	.010	.038	.233	.091[a]	.155	.054[a]	.115[a]	.110[a]	.637[a]	.031[a]	9.815[a]	1.743	1.279	20.004[a]
Std. Deviation		239.598	1.093	.007	.003	.017	.036	.015	.040	.018	.049	.027	.994	.728	4.194	.5225	.633	3.976
Range		775.700	4.100	.029	.010	.068	.144	.049	.119	.056	.166	.090	3.987	2.894	14.104	2.178	2.004	15.549
Minimum		692.100	8.600	.002	.005	.005	.144	.073	.081	.054	.115	.097	.637	.0310	9.815	1.065	.617	20.004
Maximum		1467.800	12.700	.031	.015	.073	.288	.122	.200	.110	.281	.187	4.624	2.925	23.919	3.243	2.621	35.553
Percentiles	25	787.750	9.650	.012	.008	.028	.184	.086	.092	.064	.147	.105	1.316	1.116	15.016	1.362	1.215	23.394
	50	953.500	10.400	.018	.010	.038	.224	.093	.155	.090	.195	.129	2.038	1.596	18.278	1.642	1.365	25.213
	75	1184.300	11.550	.024	.012	.052	.237	.111	.176	.099	.218	.157	2.632	2.147	22.256	1.874	2.128	29.872

a. Multiple modes exist. The smallest value is shown

Table 3: Summary of measured parameters from the study area alongside with WHO and NAFDAC approved standard for drinking water.

Parameters	Mean	Minimum	Maximum	WHO standard maximum permissible	NAFDAC Standard
Ec (µs/cm)	997.5	692.1	1467.8	1200	1000
Ph	10.605	8.6	12.7	6.9-9.5	6.5-8.5
Cd (µg/l)	0.0179	0.002	0.0310	0.003	0.003
Pb (µg/l)	0.00099	0.005	0.015	0.01	0.01
Fe (Mg/l)	0.0409	0.005	0.073	1	3
Zn (µg/l)	0.2149	0.144	0.288	3	5
Cr (µg/l)	0.0972	0.073	0.122	0.05	0.05
Cu (µg/l)	0.1405	0.09	0.2000	2	1
Mn (Mg/l)	0.0829	0.054	0.1100	0.4	20
Na^+	0.1912	0.115	0.281	250	200
Mg^{2+}	0.131810	0.097	0.187	20	20
Ca^{2+}	2.0747	0.637	4.624	75	75
K^+	1.6306	0.031	2.925	-	-
Cl^-	18.08	9.815	23.725	250	100
Ni (µg/l)	1.7073	1.065	3.243	-	-
PO_4^{3-}	1.5438	0.617	2.621	-	-
SO_4^{2-}	26.4241	20.004	35.533	500	100

From table 1, Ec ranges from 692.1 to 1467.8 and the maximum permissible limit by [19] is 1200, the NAFDAC maximum permissible limit 1000. Therefore, the valued EC in groundwater of the area is far below the permissible limit of the WHO standard. Ph ranges from 8.6 to 12.7 and the maximum permissible giant by [19] is 6.9 to 9.5, the NAFDAC maximum permissible limit 6.5-8.5.Therefore, the valued of Ph in groundwater of the area is above the permissible limit of the WHO standard. Cd ranges from 0.002 to 0.028 and the maximum permissible giant by [19] is 0.003, the NAFDAC maximum permissible ranges from 0.002 to 0.028 and the maximum permissible giant by WHO (2001) is 0.003, the NAFDAC maximum permissible limit 0.003. Therefore, the valued of cadmium in groundwater of the area is far below the permissible limit of the WHO standard. Pb ranges from 0.005 to 0.015 and the maximum permissible giant by [19] is 1200, the NAFDAC maximum permissible limit 0.01. Therefore, the valued lead in groundwater of the area is far above the permissible limit of the WHO standard. Fe ranges from 0.005 to 0.073 and the maximum permissible giant by [19] is 1, the NAFDAC maximum permissible limit 3. Therefore, the valued iron in groundwater of the area is far above the permissible limit of the WHO standard. Zn ranges from 0.144 to 0.288 and the maximum permissible giant by [19] is 3, the NAFDAC maximum permissible limit 5. Therefore, the valued zinc in groundwater of the area is far below the permissible limit of the WHO standard.

Cr ranges from 0.073 to 0.122 and the maximum permissible giant by [19] is 0.05, the NAFDAC maximum permissible limit 0.05. Therefore, the valued chromium in groundwater of the area is far above the permissible limit of the WHO standard. Cu ranges from 0.09 to 0.2000 and the maximum permissible giant by [19] is 2, the NAFDAC maximum permissible limit 1. Therefore, the value of copper in groundwater of the area is far below the permissible limit of the WHO standard. Mn ranges from 0.054 to 0.1100 and the maximum permissible giant by [19] is 0.4, the NAFDAC maximum permissible limit 20. Therefore, the valued manganese in groundwater of the area is far below the permissible limit of the WHO standard. Na+ ranges from 0.115 to 0.281 and the maximum permissible giant by [19] is 250, the NAFDAC maximum permissible limit 200. Therefore, the valued sodium in groundwater of the area is far below the permissible limit of the WHO standard.

Mg^{2+} ranges from 0.097 to 0.187 and the maximum permissible giant by [19] is 20, the NAFDAC maximum permissible limit 20 (table 3). Therefore, the valued magnesium in groundwater of the area is far below the permissible limit of the WHO standard.Ca^{2+} ranges from 0.637 to 4.624 and the maximum permissible giant by [19] is 75, the NAFDAC maximum permissible limit 75. Therefore, the valued calcium in groundwater of the area is far below the permissible limit of the WHO standard. K^+ ranges from 0.031 to 2.925 and the maximum permissible giant by [19] is 0, the NAFDAC maximum permissible limit 0. Therefore, the valued potassium in groundwater of the area is far above the permissible limit of the WHO standard. Cl^- ranges from 9.815 to 23.725 and the maximum permissible giant by [19] is 250, the NAFDAC maximum permissible limit 100. Therefore, the valued chlorine in groundwater of the area is far below the permissible limit of the WHO standard.

Ni ranges from 1.065 to 3.243 and the maximum permissible giant by [19] is 0, the NAFDAC maximum permissible limit 0. Therefore, the valued nitrate in groundwater of the area is far above the permissible limit of the WHO standard.PO_4^{3-}ranges from 0.617 to 2.621 and the maximum permissible giant by [19] is 0, the NAFDAC maximum per4missible limit 0. Therefore, the valued phosphate in groundwater of the area is far below the permissible limit of the WHO standard.SO_4^{2-} ranges from 20.004 to 35.553and the maximum permissible giant by [19] is 500, the NAFDAC maximum permissible limit 100. Therefore, the valued sulphate in groundwater of the area is far below the permissible limit of the WHO standard.

Frequency Distribution Plots: Frequency of location of collection of samples was plotted against concentration of each element (chart 1). Element considered show same trend and pattern that is, they are all asymmetrical and positively skewed. From table 2, Mean metal contents obtained in this study are a little bit lower than that obtained from values of standard deviation likewise are very low in the study area. Generally, it could be observed from the plots that all the chemical elements are asymmetrical and positively skewed. (Chart 1).

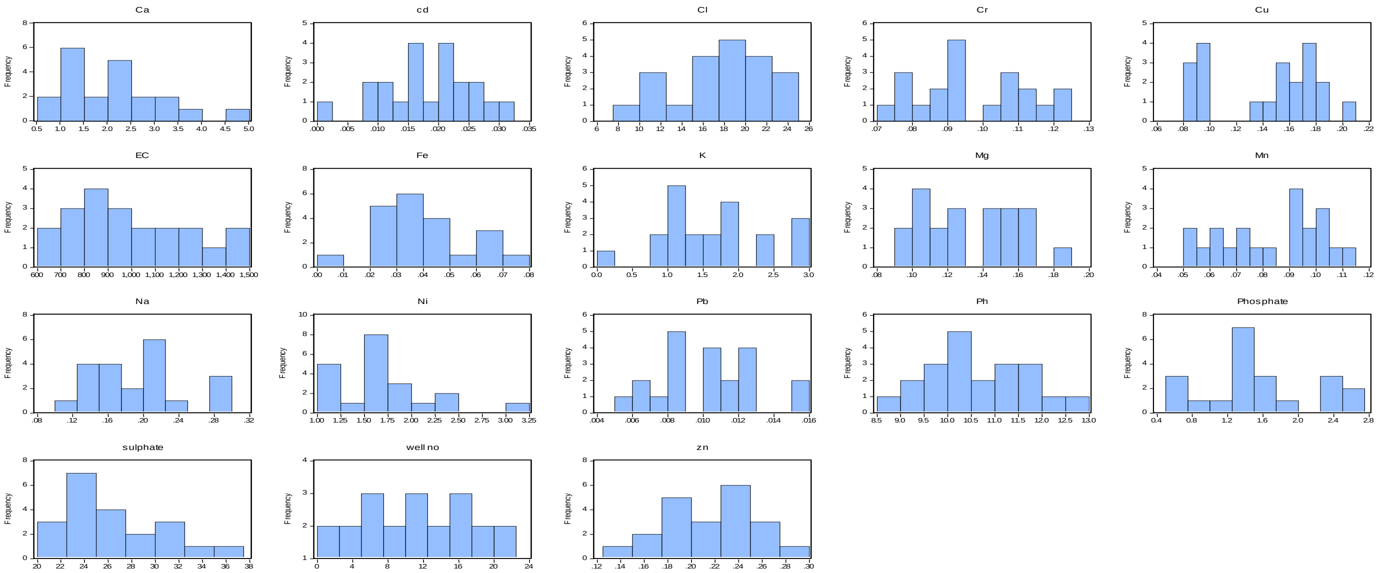

Chart 1: The frequency graph presents category and distribution value of element present in water

Table 4: Co-efficient correlation matrix of elements studied

Parameters	CA	CD	CL	CR	CU	EC	FE	K	MG	MN	NA01	NI	PB	PH	PO_4.	SO_4	ZN
CA	1																
CD	-0.442	1															
CL	-0.504	0.396	1														
CR	-0.488	0.291	0.163	1													
CU	0.634*	-0.624	-0.532	-0.484	1												
EC	0.222	-0.551	-0.049	-0.035	0.159	1											
FE	-0.355	0.575*	0.297	0.307	-0.428	-0.385	1										
K	-0.018	0.455	0.287	0.066	-0.313	-0.160	0.174	1	-								
MG	0.718*	-0.412	-0.445	-0.666	0.766*	-0.143	-0.188	-0.018	1								
MN	0.695*	-0.382	-0.381	-0.588	0.560*	0.056	-0.357	-0.039	0.761*	1							
NA01	0.790*	-0.308	-0.408	-0.442	0.470	0.017	-0.217	0.025	0.674*	0.812*	1						
NI	-0.161	-0.015	0.240	0.110	0.140	0.330	-0.029	0.185	-0.212	-0.197	-0.259	1					
PB	-0.438	-0.064	0.060	0.242	-0.562	0.171	0.132	-0.134	-0.476	-0.256	-0.210	-0.120	1				
PH	-0.104	0.124	0.253	0.051	-0.563	0.460	0.019	0.052	-0.497	-0.110	0.002	-0.012	0.575*	1			
$P0_4$	-0.061	-0.157	-0.196	0.237	0.325	0.282	-0.139	-0.184	-0.168	-0.392	-0.310	0.657*	-0.157	-0.206	1		
$S0_4$	0.502	-0.123	-0.370	-0.026	0.512**	0.200	-0.015	0.104	0.248	0.134	0.254	0.396	-0.461	-0.188	0.389	1	
ZN	0.088	0.197	0.128	-0.374	-0.200	-0.378	-0.090	0.360	0.232	0.235	0.123	-0.268	0.018	-0.053	-0.505	-0.383	1

* and ** Represents 1% (99% confidence)and 2% (98% confidence) levels

Table 4 above showed the result of the Pearson correlation coefficient analysis carried out on all samples. It showed a positive and confidence level of significant relationship between parameters. Value of CL and CA with r statistic value (r = 0.634) , FE and CD with (r = 0.575), MG and (CU, CA) with (r = 0.766, 0.718), MN and (CA, CU, MG) with (r = 0.695, 0.560, 0.761), NAO1 and (CA, MG, MN) with (r = 0.790, 0.674, 0.812), PH and PB with (r = 0.575), PO_4 and NI with (r = 0.657) all at (98, 99)% (1 & 2)% confidence level, SO_4 and CU with (r = 0.512) at 98% (2%) confidence level. It also showed a weak relationship at CL and CD with (r = 0.396), CR and (CD, CL) with (r = 0.291, 0.163), EC and (CA, CU) with (r = 0.222, 0.519), FE and (CL, CR) with (r = 0.297, 0.307), K and (CD, CL, FE,) with (0.455, 0.287, 0.174), NA01 and CU with (r = 0.470), NI and (CL, EC, CR, CU, K) with (r = 0.240, 0.330, 0.110, 0.140, 0.185), PB and (CR, EC, FE) with (r = 0.242, 0.171, 0.132), PH and (CD, CL, EC) with (r = 0.124, 0.253, 0.460), PO_4 and (CR, CU, EC) with (r = 0.237, 0.325, 0.282), SO_4 and (CA, EC, K, MG, MN, NA01, NI, PO_4) with (r = 0.502, 0.200, 0.104, 0.248, 0.134, 0.254, 0.396, 0.386), ZN and (CD, CL, K, MG, MN, NA01) with (r = 0.197, 0.128, 0.360, 0.232, 0.235, 0.123). Some parameters showed low relationship in value K and CR with (r = 0.066), MN and EC with (r = 0.056), NA01 and (EC, K) with (r = 0.017, 0.025), PB and CL with (r = 0.060), PH and (CR, FE, K, NA01) with (r = 0.051, 0.019, 0.052, 0.002), ZN and (CA, PB) with (r = 0.088, 0.018). Others showed no relationship with negative value (no correlation). Thus, high correlations show that the parameters are derived from the same source. [20]

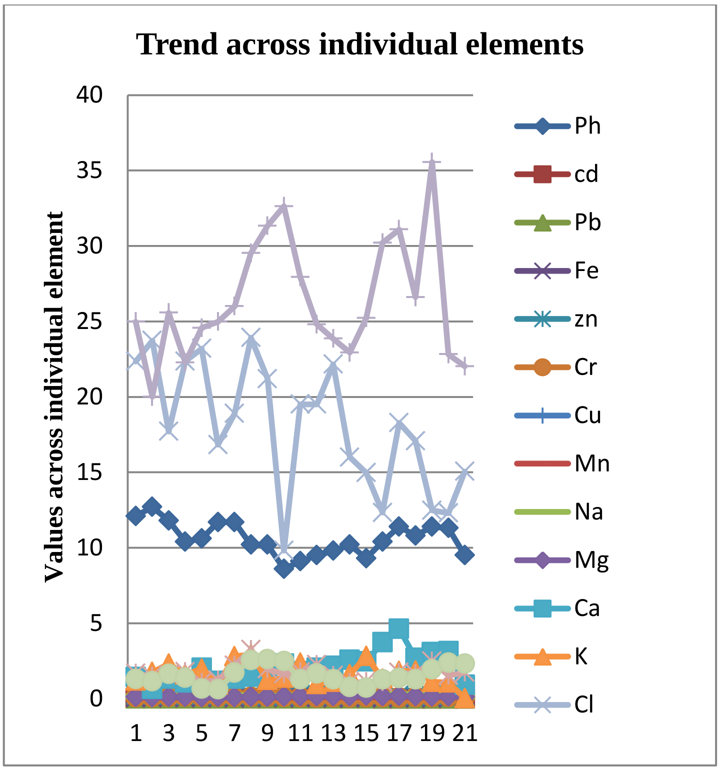

Chart 2: The chart above shows trend of element across individual element.

Sulphate (So_4), CL and PH are with value above 5 and the remaining element are from 0-5. Chart 2 showed the trend of chemical element across individual chemical elements

Scatter Diagram: Scatter diagram is employed to analyze the relationship between the elements. The plots of randomly selected element association generally revealed correlation among element considered.

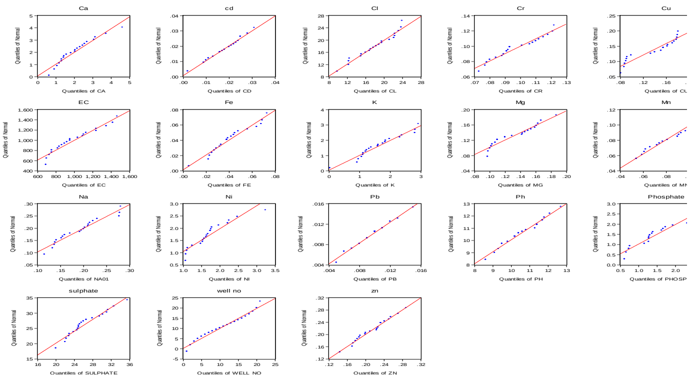

Chart 3: Scattered Plot for Regression and nearest neighbor distribution and Quartile graph

The figure above shows the scatter plot with relative to their quantiles of normal value and the quantity of element present in the water. From the scattered plots, it can be perceived that the points are reasonably closely scattered about an underlying straight lines as against to the curves. Therefore, it can be said that there is a strong linear relationship between the chemical parameter. The scattered plot showed that as the quantiles of normal increases so the quantiles of the parameter increases.

IV. CONCLUSION

Applying multivariate statistical methods on hydrogeochemical parameters of the water quality of part of Igboora Ibarapa, the study indicates elements considered show same trend and pattern that is, they are all asymmetrical and positively skewed. The implication of this trend on water is that the metal contents falls within the W.H.O standard. The concentration of element present is only due to lithological composition of the bedrock. It can be concluded that the sampled groundwater are in most cases suitable for human consumption judging by the various concentration of the hydrogeochemical parameters analysed from the samples and in comparison with World Health Organisation standard. The result of the correlation will help in understanding geochemistry of the study area It was also observed that all the heavy metals, anions and cations, and other chemical parameters are far lower than the WHO acceptable standard for drinking water.

The outcome of this study makes the following recommendations inevitable:

i. That further investigation of the entire area is necessary to determine the specific causes for the chemistry observed and to establish hypotheses for the observation;

ii. For the research approach, a large number of samples should be taken to allow the optimization of a more routine study in the area; and

iii. They should be properly orientated on the need not to dump untreated/raw sewage into the hand dug well waters and the environments so as to reduce the increasing rate of fecal contamination of both the surface and groundwater bodies from where majority of domestic water supply come from

V. REFERENCES

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