Hydro-geochemical Investigation of Groundwater and Surface water Quality in Minna Metropolis North Central, Nigeria

Sodangi, A.A [1]., Esuabanga, W.E [2]., Ologun, S [3]. and Osuorji, G.C [4].

[1, 2, 3, 4]*Nigerian Building and Road Research Institute (NBRRI) Km 10 Idiroko Road, Ota, Ogun State, Nigeria*

Abstract - *This study investigated the trend of ground and surface water quality for drinking and irrigation purposes in Minna Metropolis. Geologically, the area consists of granite and gneiss. Twenty-four water samples were collected (7-surface and 17 groundwater) and subjected to physiochemical analyses. The instruments used in the field were bottles, thermometer, electrical conductivity (EC) and pH meter. The water analysis results showed abundance of major cations and anions of ground water in the following order:* $Mg^{2+}>Na^{+}>Ca^{2+}>K^{+}>Cu^{2+}>Fe^{2+}>Pb^{2+}$ *and* $SO_4^{2--}>PO_4^{3-}>NO_3^{-}>CO_3^{2-}>Cl^{-}>HCO_3^{-}$, *while in surface water the order was:* $Mg^{2+}>Ca^{2+}>Na^{+}>K^{+}>Cu^{2+}>Fe^{2+}>Pb^{2+}$ *and* $SO_4^{2-}>PO_4^{3-}>NO_3^{-}>CO_3^{2-}>Cl^{-}>HCO_3^{-}$. *The results showed that water resources of the area is alkaline in nature and* SO_4^{2-}, PO_4^{3-}, NO_3^{-}, Mg^{2+}, Ca^{2+} *and* Na^{+} *were the major contributing ions to the dissolved solids. Hydro-geochemical data suggest that weathering of rock forming minerals, agricultural runoff, anthropogenic and waste disposal sources are the major factors affecting water resources of the study area. Total hardness (TH) analysis revealed that the water is moderately hard to very hard in nature. The study also revealed that the water samples are within prescribed limit of mg/l by WHO for drinking purpose. Piper diagram for the study area showed that there is a mixture of three types of water. These are:* $Ca\text{-}Mg\text{-}SO_4$, $Na\text{-}K\text{-}SO_4$ *and* $Ca\text{-}Mg\text{-}SO_4\text{-}Cl$. *The calculated sodium adsorption ratio (SAR), residual sodium carbonate (RSC), Kelley's ratio (KR) and sodium percentage (Na %) suggest that the water is suitable for irrigation. However, magnesium ratio (MR) suggests that of all the 24 points, only three locations are suitable for irrigation. The concentrations of Fe, Pb,* CO_3^{2-} *and Cu exceeded the WHO permissible limit (0.3, 0.05, 0.1 and 1.3) mg/l in some water samples. The values of total dissolved solids (TDS) suggest that both ground and surface water were fresh water type (<1000) mg/l.*

Keywords - *Hydro-geochemical; Irrigation; Major ions; Minna metropolis, water quality*

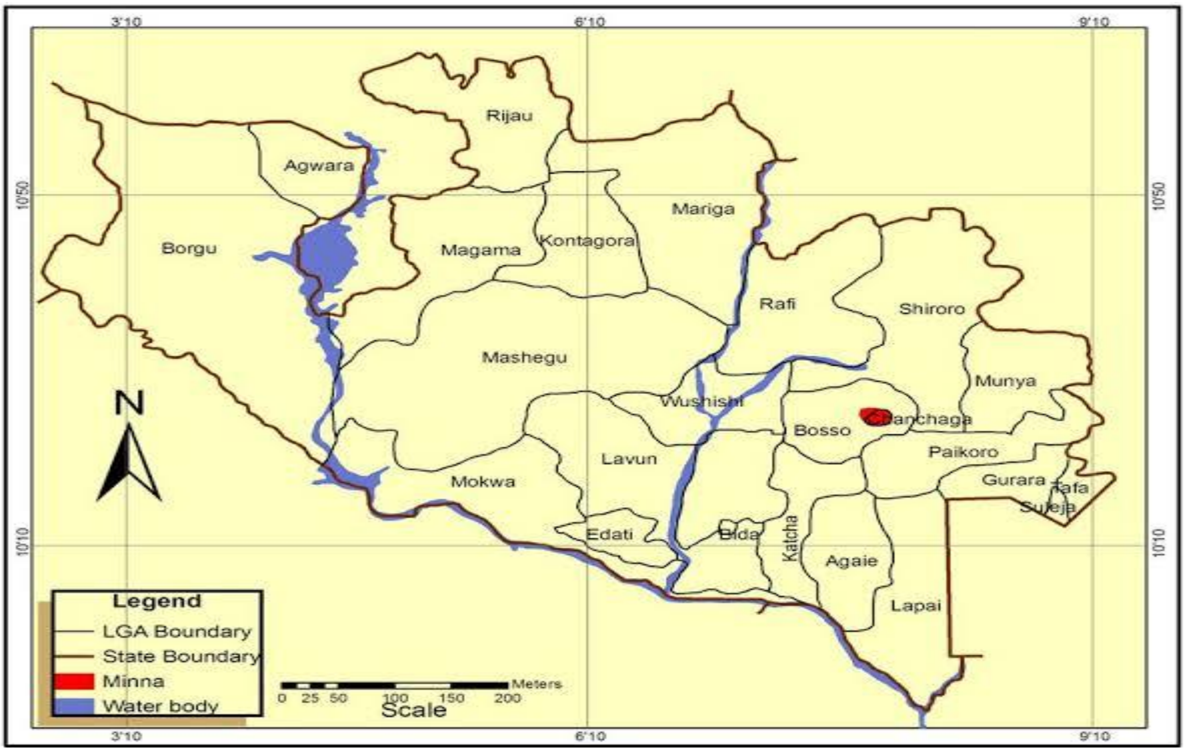
I. INTRODUCTION

Hydro-geochemical study of water sources involves the studying of the chemistry /geochemical elements of water, nature and quality of water in relation to its geology and waste disposals. Water is one of the most essential elements to good health and it is one of the nature's most important gifts to life. It is necessary for digestion and absorption food. Water has always played a key role in supporting life in various ways. Therefore, the quality of accessible water is an important index of the living standard [2]. More importantly research has also shown that mineralogical composition of the underlying rocks and the nature of the surface run off are factors that affect quality of ground water.

In addition, ground water is one of the most essential sources of water to mankind, in the sense that it is not easily contaminated [19]. The quality of ground water is largely controlled by discharge-recharge pattern, nature of host and associate rocks as well as contaminated activities. The quality of ground water is a function of various parameters which determine its suitability for drinking purposes [18]. Environmental activities and human interference are the main causes of change in the ground water quality [8]. In modern times, water resources have critical importance in the economic growth of all contemporary society. Recently, population growth, urbanization, and intense agricultural and industrial activities have caused tremendous increase in demand for fresh water [7]. In view of all these points, there is an urgent need to evaluate the trend of ground and surface water quality for drinking and irrigation purpose.

II. LOCATION OF THE STUDY AREA

The study area lies between latitudes 9° 33' to 9° 40’ N and longitudes 6° 29’ to 6°35,’E covering an area of about 334km^2, with an average altitude 298.70m as shown in Figure 1. The area is located in Chanchaga Local Government Area of Niger State and its part of Minna sheet 164. Suka and Barako are the major rivers in the area controlling the drainage pattern and natural slope of the area. The river irrigates northern and southern part of the study area. The area has a tropical climate which is characterized by hot summer and cold winter. The average rainfall is between 1200 and 1450mm. About 90 percent of the rainfall takes place from May to September. Its relative humidity is 74%.



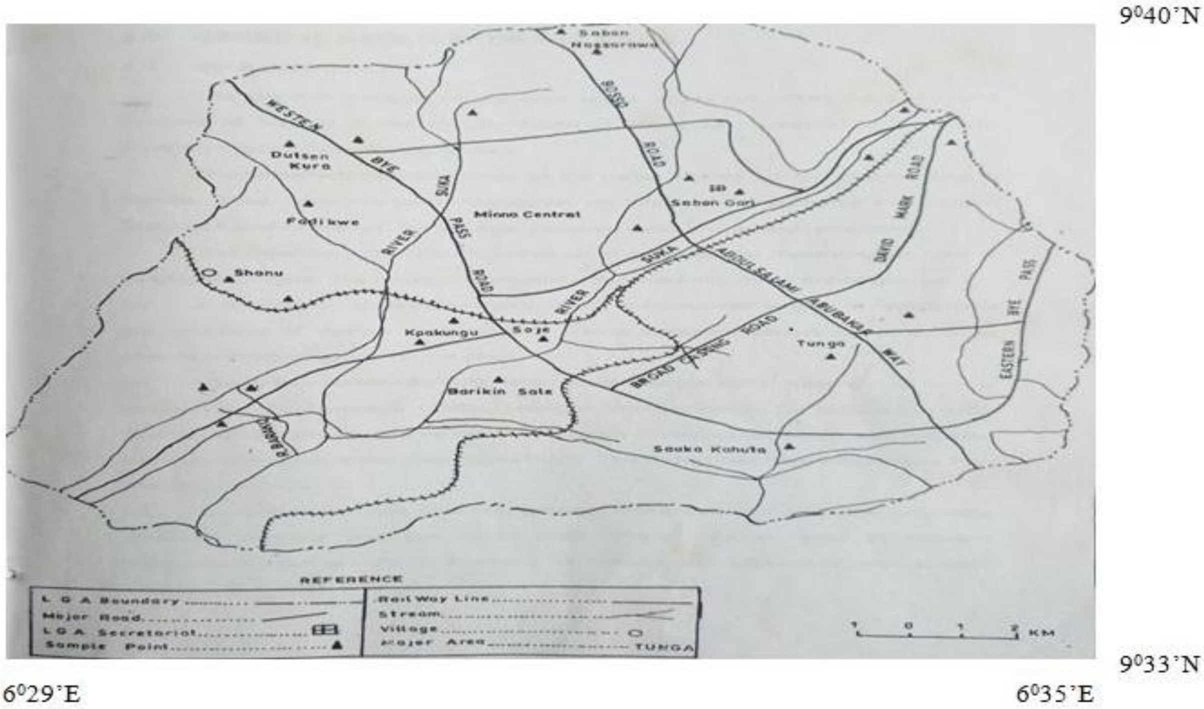
Source: [5]

Fig. 1 Map of Niger State showing the study area Minna.

III. GEOLOGY AND HYDROGEOLOGY

The geology of the study area falls within the basement complex of Nigeria. It lies directly south of sheet 32 Kusheriki of the North Western Nigeria basement complex. The basement rocks as the name implies are the oldest rocks in Nigeria. They form the base foundation on which the sediment had been deposited and into which the younger intrusive rock had been emplaced. The basement complex is made up of igneous and metamorphic rocks of varying lithology. The rocks are generally classified into three broad groups; (a) A polymorphic complex, which is composed largely of migmatites and gneisses of various compositions. Relics of meta-sedimentary rocks such as quartzite rocks occur within the area. (b) Low grade meta-sediments, which form narrow belts, describe as “never meta-sediments”, younger meta-sediments [6]. The schist belt believed to be relics of a supra crustal cover which was in folded into migmatites gneisses complex [12]. The schist belts are intruded by Pan African granitoids. The granitoid has been emplaced into both the migmatite- gneiss complex and the schist belts, and they occur in all part of Nigeria [1]. (c) Syntectonic to late tectonic rocks that out both the Migmatites gneisses complex and the schist’s belts. These include rocks of different composition from granite to batholite to tantalite and charnockite with smaller bodies. The migmatite -gneiss complex are considered to be the basement sensu-stricto and isotropic ages varying from Liberian to Pan-African and have been interpreted as due to isotropic rehomogenisation in pre-existing rocks during the African orogenic [10].

The hydrogeology of the area, are those that recharged by precipitation and run-off from high land during the wet season. Most of the streams are seasonal and hence dries up during the dry season. Others flow all year round and may be recharged from fractures or seep in the underlying fractured basement as the rivers or streams are observed to be structurally controlled. The importance of rivers and streams as source of water is reflected in the concentration of settlement near these rivers or streams. The surface water serves as the main sources of water for irrigation and cattle rearing



IV. MATERIALS AND METHODS

The instruments used in the field were bottles, thermometer, electrical conductivity and pH meter. Temperature, EC and pH values were measured in the field using portable conductivity and pH meter (Kent Eil Model 7045/47). Twenty-four (24) sampling locations were identified and 2 liter of water was collected from each location as reflected in Figure 2. Five samples collected from tube well and twelve samples collected from dug well are representing the ground water sources. Surface water collected were six samples from stream and one sample from tap. Nitric acid was added into one part of samples from each location to avoid bacteria growth and ion precipitation in the solution. All samples were tightly covered and taken to laboratory for analysis. Na and K was determined using flame photometer, NO_3 was determined using UV spectrophotometer. SO_4^{2-} and PO_4^{3-} was determined using calorimeter. Fe, Pb, Ca, Cu and Mg were measured using atomic absorption spectrophotometer (AAS) in a flame mode, after calibrating the instrument with known standards. Before each element was analyzed, standard solution of each elements was prepared for standardization of the instruments. CO_3^{2-}, $HCO_3^-$and Cl were measured using titrimetric method. Total Dissolved Solids was determined according to [13].

V. RESULTS AND DISCUSSION

A. Drinking Water Quality

The temperature of ground water (dug and tube wells) samples ranged from 25 to 29^{o}C with average of 26.5^{o}C while, surface water (stream and tap) samples ranged from 25 to 28^{0}C with an average of 26.1^{0}C. According to [18], no limit was set for drinking water temperature. pH values of the ground water analyses ranged from 6.0 to 7.44 with an average of 6.7 while, the surface water ranged from 5.99 to 7.4 with average of 5.7. The results suggest neutral to alkaline nature of water sources. The pH of natural water is most often controlled by the carbon dioxide bicarbonate carbonate system (Figure 3). PH alone cannot be the ultimate factor which is fit for drinking but also many other parameters contributes to it to state whether the water is fit or not [20]. Electrical conductivity (EC) values of ground water samples analyses ranged from 60 to 1480µS/cm with an average of 652µS/cm while surface water samples ranged from 60 to 405µS/cm with an average of 160µS/cm. As evident from Table 1, most of the water samples were within the limit (<2000). Concentration of Total Dissolved Solid (TDS) of ground water ranged from 64.59 to 96.62 mg/l with an average of 79.59 mg/l while surface water ranged from 93.02 to 190.21mg/l with an average of 159.69 mg/l. This indicates that more than 95% of the water samples are categorized as fresh water (TDS<1000) mg/l, as shown in Table 5. The Statistical mean distribution of Temperature, EC and pH is given in Table 2 below.

Table 1: Values of electrical conductivity, temperature and ph in water samples

S/N	LOCATION	TYPE	TEMPERATURE(°C)	CONDUCTIVITY(µS/cm)	pH
1	I	Tube well	26	1.8 x 100	6.50
2	II	Dug well	26	3.2 x 100	6.77
3	III	Stream	28	0.7 x 100	7.40
4	IV	dug well	26	14.1 x 100	7.00
5	V	Dug well	27	14.8 x 100	6.35
6	VI	Stream	25	1.85 x 100	6.50
7	VII	Dug well	27	3.85 x 100	6.95
8	VIII	Stream	26	4.05 x 100	5.99
9	IX	Dug well	27	4.50 x 100	7.30
10	X	Dug well	25	7.05 X 100	7.07
11	XI	Stream	25	2.0 X 100	6.60
12	XII	Tube well	28	0.6 x 100	6.85
13	XIII	Stream	27	0.6 X 100	6.90
14	XIV	Dug well	27	5.05 x 100	6.70
15	XV	Dug well	28	3.5 x 100	7.25
16	XVI	Tube well	25	3.7 x 100	7.44
17	XVII	Dug well	25	11.40 x 100	6.50
18	XVIII	Tube well	29	1.6 x 100	6.15
19	XIX	Tube well	26	3.8 x 100	6.84
20	XX	Stream	27	1.0 x 100	7.05
21	XXI	Dug well	27	13.3 x 100	6.00
22	XXII	Tap	25	1.0 x 100	6.75
23	XXIII	Dug well	26	7.2 x 100	6.78
24	XXIV	Dug well	27	11.40 x 100	6.15

Table 2: Mean values of pH, electrical conductivity and temperature in water samples

SAMPLE SOURCES	MEAN pH	MEAN CONDUCTIVITY(µS/cm)	MEAN TEMPERATURE(°C)
Dug well	7.04	8.09 X 100	26.6
Stream	6.67	1.84 X 100	26.2
Tube well	6.93	2.75 X 100	26.3
Tap	6.69	1.25 X 100	25.5

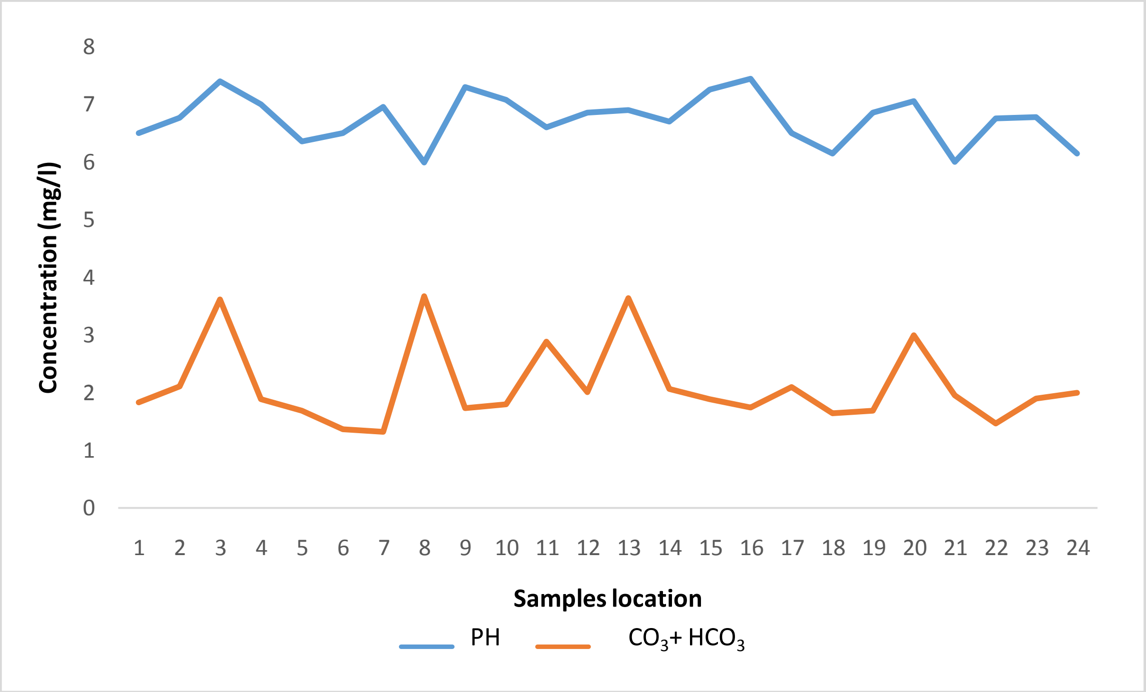


Fig 3: Relationship of PH/CO_3+HCO_3

The Sodium concentration of ground water ranged from 6.25 to 18.5mg/l with an average of 11.5 mg/l constituting 22.7% of the total cations mass balance (TZ) while, the surface water samples ranged from 7.8 to 24.5mg/l with an average of 18.6 mg/l accounting for 17.5% of the total cations (TZ) charge balance. These shows the values are below permissible limit (<200). The concentration of Pb in groundwater ranges from 0.2 to 1.2 mg/l (avg. 0.5) mg/l. While in surface water its ranges from 0.33 to 2.11 mg/l (avg. 1.3) mg/l. The values obtained from all the water samples exceed permissible limit (>0.05) of WHO for drinking water. Results from Pb pipes, fixtures, faucets and leached of waste disposal. Concentration of K in ground water ranged from 5.75 to 18.5 mg/l with an average of 8.6 mg/l constituting 17% of the total cations mass balances. Surface water sample ranged from 6.3 to 15.75 mg/l with an average of 13.8 mg/l constituting 13% of the total cations mass balance (Table 3). The result showed that all locations are good quality with respect to this parameter according to the WHO criteria. In surface water, concentration of K slightly increased and this occurred as a result of washing down agricultural chemical to the streams. Magnesium concentration of ground water analyses ranged from 11 to 30 mg/l with an average of 17.6 mg/l constituting the highest percent (34.8%) of the total cations mass balance (TZ). In surface water the values ranged from 18 to 64 mg/l with an average of 45.1 mg/l constituting also the highest percent (42.4%) of the total cations mass balance. This indicates that all the values were within the desirable limit (<30) except in surface water location 3,6,8,11,13 and 22 which their values were above desirable limit, denoting supply of Mg from weathering of dolomite. However, the values are below permissible limit (<100) as stipulated by WHO for safe drinking water (Table 3).

Table 3: Geochemical analyses of ground and surface water samples of the study area (mg/l)

S/N	Na	K	Ca	Mg	Cu	Fe	Pb	TH	CL	NO_3	SO_4	HCO_3	CO_3	PO_4
1	12	6.25	8	30	0.6	1	0.23	143	0.56	1.7	11	0.0308	1.802	4.3
2	10	5.75	10	29	0.78	0.94	0.31	144	0.63	2.9	16.4	0.3048	3.067	5.4
3	16	13.3	17	39	1.14	2.67	1.21	203	1.82	9.65	34	0.0628	3.551	18
4	8.26	9.7	7	13	0.69	0.36	0.42	71	0.91	4.2	8.5	0.0268	1.855	9.75
5	9.3	10.2	12	15	0.35	0.62	0.5	95	1.02	6.2	12.75	0.0448	1.643	7.5
6	21.5	12.5	20	61	1.45	2.03	1.08	301	1.65	9.8	23	0.0828	1.272	7.75
7	15.5	8.35	9	18	0.28	0.39	0.22	96.5	0.46	6.4	11.7	0.0388	1.277	7.75

8	23	15.2	34	45	1.16	1.89	1.66	270	1.75	13.45	20.7	0.0708	3.604	28.75
9	12.35	10.45	12	15	0.84	0.23	0.49	91.7	1.02	4.6	15.7	0.0368	1.696	12.5
10	13	8.3	8	19	0.8	0.43	0.43	98.2	1.26	5.5	16.75	0.0408	1.749	9.5
11	20.15	14.5	22	64	1.92	2.7	1.19	318	2.14	8.9	19.5	0.0768	2.809	24.4
12	6.75	9.3	18	14	0.75	0.18	0.32	103	0.88	4.8	15	0.0448	1.961	6
13	17.5	15.75	36	52	1.62	2.85	1.34	304	1.89	9.8	19.85	0.0868	3.551	17.2
14	18.05	7.8	10	17	0.7	0.61	0.28	94.9	1.12	4.3	7.9	0.0508	2.014	5.75
15	8.5	10.7	9	12	0.45	0.72	1.01	71.9	1.23	5.9	6.5	0.0328	1.855	7
16	10	7.5	11	26	0.49	0.81	1.2	135	1.33	6	11.3	0.0428	1.969	19
17	12.5	6.9	18	20	0.82	0.99	0.37	127	0.81	4	9.7	0.0264	2.067	10
18	17.25	11.25	9	16	0.86	0.66	0.25	88.3	1.05	3.7	10.3	0.0448	1.59	7.2
19	14.85	11	7	11	0.87	0.6	0.48	62.7	1.3	5.2	12	0.0348	1.643	5
20	24.5	18.75	27	18	1.81	1.89	2.11	142	1.44	9	21.3	0.0808	2.915	22.75
21	10.75	7.2	32	13	0.72	0.35	0.54	133	0.77	3	8.8	0.0448	1.908	14
22	7.8	6.3	13	37	0.99	0.52	0.33	185	1.93	2.4	13	0.0328	1.431	8.3
23	9.3	11.58	8	14	0.63	0.8	0.2	77	1.37	4.7	12.45	0.0366	1.855	12.5
24	7.5	10.4	14	17	0.67	0.42	0.44	105	1.16	5.6	10	0.0388	1.961	10.7

Note: TH=Total Hardness.

Calcium concentration of ground water varied from minimum value of 7.0 to maximum of 32.0mg/l with an average of 11.2mg/l constituting 22.1% of the total cations mass balance while surface water ranged from 13 to 36mg/l with mean of 24.1mg/l accounting for 22.7% of the total cations mass balance (TZ). Table 3 shows that all the samples from the study area exhibited Ca concentration below permissible limit (200). High Ca concentration in water may lead to formation of solid scales in pipes and increased soap consumption. Cu concentration of ground water analyses ranged from 0.28 to 0.87mg/l with an average of 0.6mg/l accounting for 1.2% of the total cations mass balance. Surface water ranged from 0.99 to 1.92mg/l with an average of 1.4 mg/l accounting for 1.3% of the total cations mass balance (TZ). All the values obtained from ground water samples were below the permissible limit (<1.3) mg/l.

However, locations 6, 11, 13 and 20 of surface water exceeded the permissible limit (1.3), and this could be attributed to transportation of decay waste disposal and industrial waste water within the environment to streams. Concentration of Fe in ground water ranged from 0.18 to 0.99mg/l with an average of 0.6 mg/l constituting 1.1% of the total cations mass balance. In surface water, it ranged from 0.52 to 2.7 mg/l with an average of 2.1 mg/l constituting 1.9% of the total cations mass balance. The results showed that the values obtained from all the samples exceeded permissible limit (0.3) except locations 9 and 12. This could be attributed to weathering of Fe bearing minerals which led to release of large quantity of Fe in solution down to streams.

$$\mathrm{TH} = (2.497 \times Ca) + (O4.115 \times Mg) \qquad (1)$$

Total Hardness (TH) of both ground water and surface water samples in the study area varied from 62.7 to144.3 and 141.5 to 318.3 mg/l respectively, indicating moderately to very hard type water [9]. Hard water is mainly account of the unpleasant taste and reduces the ability of soap to produce lather. The results revealed that the values were below permissible limits of drinking water.

Sulfate concentrations of ground water varied from 6.5 to 16.74mg/l with an average of 11.6 mg/l constituting 40.6% of total anions mass balance. Surface water ranged from 13 to 34 mg/l with an average of 21.6 mg/l accounting for 40.5% of total anions mass balance. It is important that SO_4^{2-} contents in most of the samples were below the WHO standard as reflected in Figure 4. Slight increase in SO_4^{2-} of surface water may be attributed to weathering of sulfate and gypsum minerals or anthropogenic sources like industrial and agricultural runoff. Actually $SO_4^{2-}$is mostly found in a dissolved form [14]. HCO_3^-concentrations in ground water varied from 0.026 to 0.0508 mg/l with an average of 0.37mg/l accounting for 1.4% of total anions mass balance. Surface water ranged from 0.032 to 0.087 mg/l with an average of 0.07mg/l constituting 0.1% of total anions mass balance. All the values were within permissible limit of safe drinking water. Weathering of carbonates and alumina-silicate minerals with secondary contribution from dissolution of CO_2 gases are primary source of HCO_3^- in the ground water [4]. The reaction is shown below:

$$CO_2 + H_2O = H^+ + HCO_3^- \qquad (2)$$

Carbonates concentration of ground water ranged from 1.28 to 3.604 mg/l with an average of 1.8mg/l constituting 6.3% of total anions mass balance.

Surface water ranged from 1.27 to 7.73mg/l with an average of 2.7mg/l accounting for 5.1% of total anions mass balance. The permissible limit of CO_3 from WHO are 0.1mg/l and the chemical data revealed that all the water samples exceeded the limit. Concentrations of NO_3^- in ground water varied from 1.7 to 6.4 mg/l with an average of 4.6 mg/l accounting for 11.1% of total anions mass balance while surface water ranged from 2.4 to 13.45 mg/l with an average of 9.0 mg/l constituting 16.8% of total anions mass balance (TZ).The results showed that all the values were within the desirable limit as captured in Table 4. Slight increase in NO_3^- contents in surface water might have originated from atmospheric precipitation, agricultural fertilizer, human and animal excretion, biological fixation and nitrification of organic nitrogen. However, the values were below permissible limit as shown in Table 4.Chlorine concentration of ground water ranged from 0.45 to 1.36mg/l with an average of 1.1 mg/l accounting for 3.8% of total mass balance (TZ). Surface water ranged from 1.43 to 2.13 mg/l with an average of 1.8mg/l constituting 3.4% of total anions mass balance. The results revealed that the values of analyses samples in the study area were below WHO desirable limit. Cl in natural water may originate from both natural and anthropogenic sources. Weathering of halite and evaporate are the major sources of Cl in ground water. PO_4^{3-} concentration of ground water ranged from 4.3 to 12.5 mg/l with an average of 9.1 mg/l constituting 31.8% of total anions mass balance (TZ). In surface water, the values varied from 8.3 to 28.7 mg/l with an average of 18.2) mg/l accounting for 34.1% of total anions mass balance. No provision for PO_4^{3-} in WHO's standard, however, the main source of PO_4^{3}- in a natural water comes from plant remains, agricultural chemical and industrial waste. Chemical data analyzed, revealed that the concentrations of Carbon dioxide, Lead and Iron in the study area exceeded permissible limit of 0.1, 0.05 and 0.3 mg/l respectively, in almost all the locations as shown in Figure 4. This implies that the sampled waters are not suitable for safe drinking purpose as well as Industrial process. Excess of these elements may cause carbonate hardness, convulsion in children and hemochromatosis.

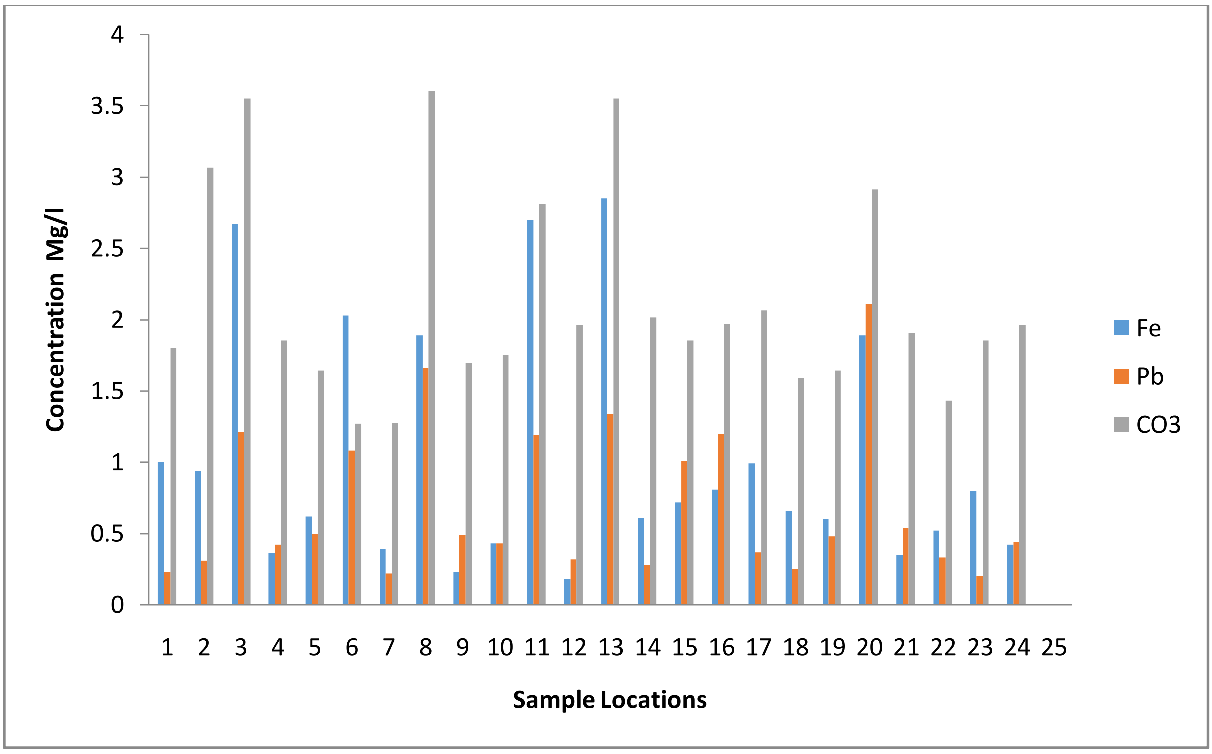


Fig 4: Relationship of Fe/Pb/CO_3.

For a better understanding of chemical characteristics of water resources and its relationships with the dissolved ionic constituents, the hydro chemical data has been plotted on a Piper diagram [11]. It shows that there is a mixture of three types of water from the study area. Base on the dominance of different cations and anions in the water, the hydro chemical water types that were found are: Ca-Mg-SO4, Na-K-SO4 and Ca-Mg-SO4-Cl as shown in Figure 5, denoting dominance of Magnesium and Calcium (alkaline earth) over Sodium and Potassium (alkalis). The abundance of alkaline earth elements contents reflecting dissolution of Magnesium and Calcium bearing minerals in geological formation while the alkalis elements may be attributed to weathering of feldspar minerals in the water.

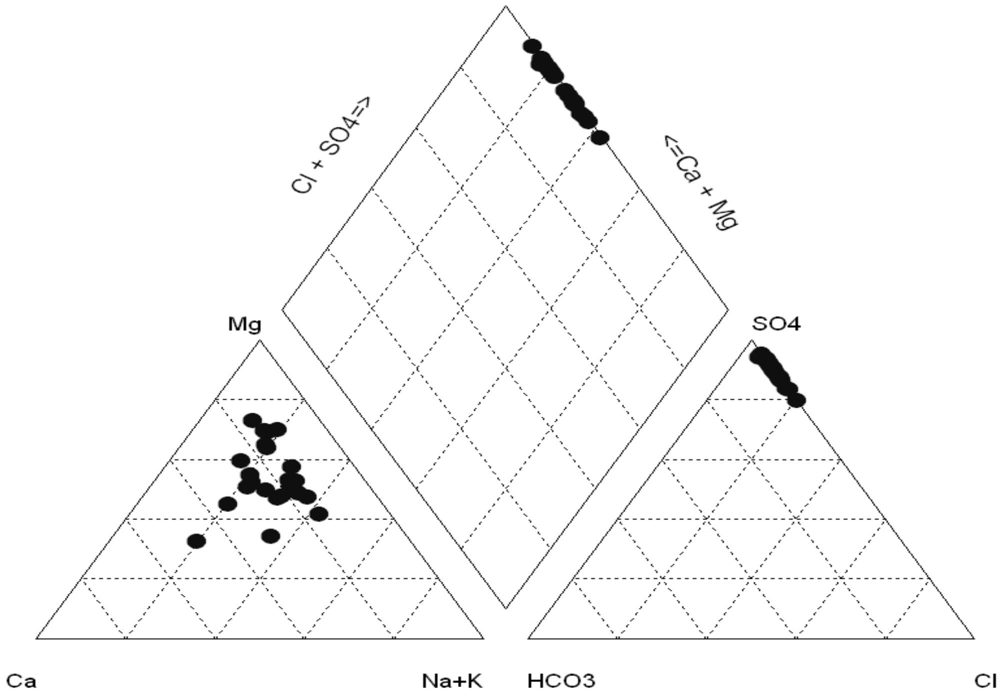


Fig. 5 Piper diagram showing hydro-geochemical character of water samples.

Table: 4 Comparisons of the quality parameters of ground and surface water of the study area.

Water quality parameters	Ground Water(GW)			Surface Water(SW)			NGW	NSW	Desirable WHO Limit	Permissible WHO Limit
	MIN	MAX	AVE	MIN	MAX	AVE				
PH	6	7.44	6.7	5.99	7.4	5.7	0	0	6.5-8.5	8.5-9.2
EC	60	1480	652	60	405	160	0	0	750	2000
Temp	25	29	26.5	25	28	26.1	-	-	-	-
Cal	0.45	1.36	1.1	1.43	2.13	1.8	0	0	250	1000
HCO_3	0.026	0.0508	0.37	0.032	0.087	0.07	0	0	200	600
NO_3	1.7	6.4	4.6	2.4	13.45	9	0	0	50	100
SO_4	6.5	16.75	11.6	13	34	21.6	0	0	200	400
Ca	7	32	11.2	13	36	24.1	0	0	75	200
Mg	11	30	17.6	18	64	45.1	0	0	30	100
K+	5.75	18.75	8.6	6.3	15.75	13.8	-	-	-	-
Na	6.75	18.5	11.5	7.8	24.5	18.6	0	0	200	-
PO_4	4.3	12.5	9.1	8.3	28.7	18.2	-	-	-	-
Cu	0.28	0.87	0.6	0.99	1.92	1.4	0	4	1	1.3
Fe	0.18	0.99	0.6	0.52	2.7	2.1	15	7	0.3	0.3
Pb	0.2	1.2	0.5	0.33	2.11	1.3	17	7	0.05	-
CO_3	1.28	3.64	1.8	1.27	2.73	2.7	17	7	0.1	-
TDS	64.59	96.62	79.59	93.02	190.21	159.69	0	0	1000	-

Note: Min=Minimum value, Max=Maximum value, Ave=Average value, SD=Standard Deviation, NGW means N=No. of locations which exceed max. Permissible limit of ground water (GW) and SW means surface water.

Table: 5 Characteristic ratios of ground and surface water samples of the study area.

LOCATION	SAMPLE SOURCE	KR(mg/l)	RSC(mg/l)	MR(mg/l)	Na%	SAR(mg/l)	TDS(mg/l)
1	Tube Well	0.32	-36.2	78.9	32.4	2.68	77.46
2	Dug Well	0.26	-30.9	74.4	28.8	2.26	85.35
3	Stream	0.29	-52.4	69.6	34.3	3.02	156.38
4	Dug Well	0.41	-18.1	65	47.3	2.61	64.67
5	Dug Well	0.33	-26.3	57.1	41.1	2.48	77.10
6	Stream	0.27	-79.6	75.3	29.6	3.37	163.08
7	Dug Well	0.57	-25.7	66.7	46.9	4.21	79.35
8	Stream	0.29	-75.3	57	32.6	3.65	190.21
9	Dug Well	0.46	-25.3	55.6	45.8	3.36	86.90
10	Dug Well	0.48	-25.2	70.4	44.1	3.53	84.74
11	Stream	0.23	-85.1	72.7	28.3	3.07	184.25
12	Tube Well	0.21	-30	43.8	33.4	1.68	77.96
13	Stream	0.29	-84.4	59.1	27.4	2.63	179.4
14	Dug Well	0.64	-24.9	63	49.1	4.96	75.55
15	Dug Well	0.4	-19.1	57.1	47.8	2.62	64.88
16	Tube Well	0.27	-35.3	70.3	32.1	2.32	96.62
17	Dug Well	0.33	-35.9	52.6	33.8	2.86	86.17
18	Tube Well	0.69	-23.4	64	53.3	4.87	79.14
19	Tube Well	0.83	-16.3	61	58.9	4.95	70.96
20	Stream	0.54	-42	40	49	5.16	151.51
21	Dug Well	0.24	-43	28.9	28.5	2.26	93.06
22	Tap	0.16	-48.5	74	27.7	1.56	93.02
23	Dug Well	0.42	-20.1	63.6	46.9	2.80	77.40
24	Dug Well	0.24	-29	54.8	36.6	1.90	79.87

Note: KR=Kelley Ratio, RSC=Residual Sodium Carbonate, MR=Magnesium Ratio, SAR=Sodium Adsorption Ratio and Na% Sodium Percentage.

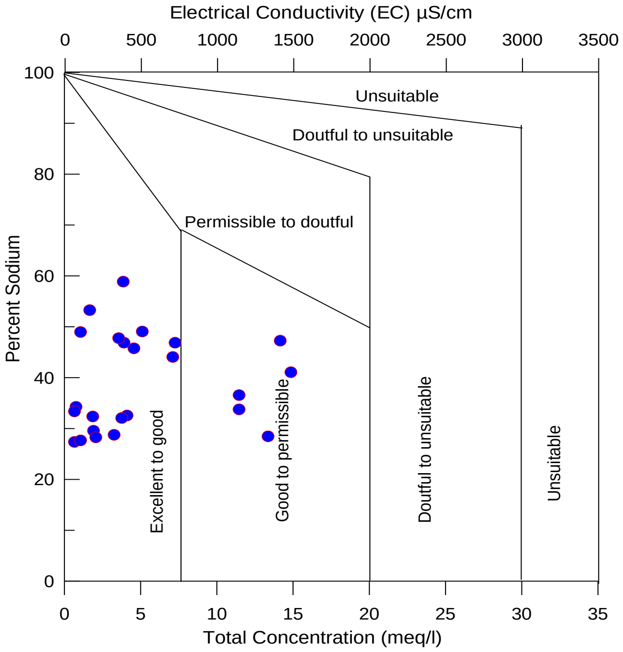


Fig 6: plot of Percentage sodium against EC (after Wilcox 1955).

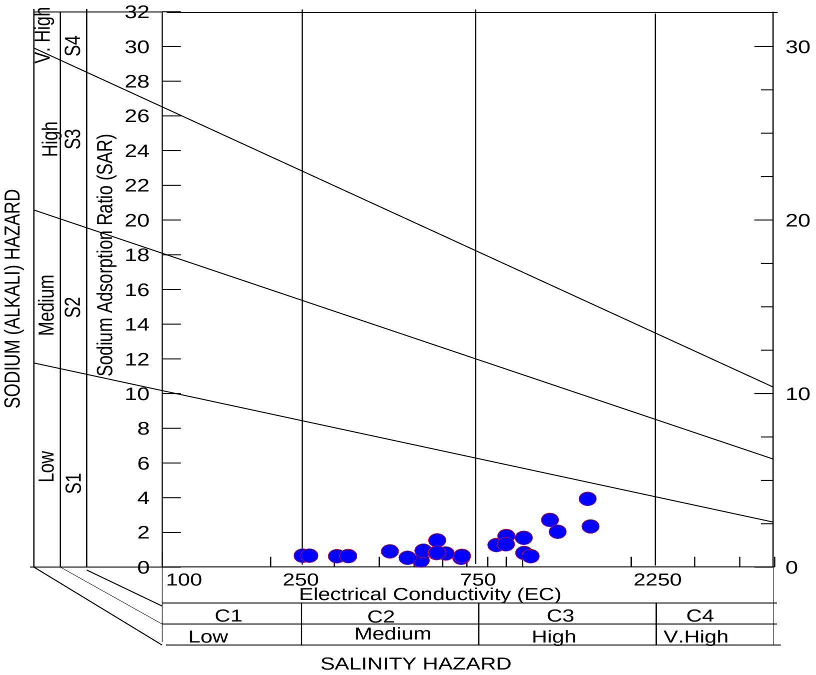


Fig 7: U.S. salinity diagram [USSL] for classification of irrigation water.

B. Irrigation Water Quality

The important parameters which were used for assessing the suitability of water for irrigation purpose are given below:

1) **Sodium Percentage (Na %)**: is calculated by the formula:

$$Na\,\% = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} X\ 100 \qquad (3)$$

The classification of irrigation water based on the values of sodium percentage as proposed by [17], suggests that both the ground and surface water of the study area are excellent to good and good to permissible (Figure 6). Sodium percent value of both the ground and surface water ranged from 28.5 to 58.9 and 27.4 to 49 %. This shows that the values are below maximum sodium percent limit (<60%), therefore good for irrigation.

2) **Sodium Adsorption Ratio (SAR)** is given by:

$$\frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}\text{Mg/l} \qquad [15] \qquad (4)$$

Irrigation with high sodium water cause exchange of Na^+ in water for Ca^{2+} and Mg^{2+} in soil reduced the permeability of the soil. Both the ground and surface water in the study area had SAR values ranging from 1.65 to 4.95 and 1.56 to 5.16 mg/l respectively. According to [17], water with SAR <10 is considered as an excellent quality. The plot of US Salinity (1954) diagram shows that the water samples at the study area fall in C1S1, C2S1 and C3S1 field signifying good to moderate quality of water for irrigation (Figure 7), whereas C1, C2, C3 and S1 exhibited low saline, medium saline, high saline and low sodium hazard respectively . The good water (C1S1 and C2S1) can be used for irrigation of most crops and soils with little danger of exchangeable sodium while moderate water (C3S1) may be used to irrigate salt tolerant crops under favorable drainage condition.

3) **Residual Sodium Carbonate (RSC)**:

$$[Co_{3^-} + Hco_{3^-}] - [Ca^{2+} + Mg^{2+}]mg/l \qquad (5)$$

RSC is used to know the quantity of complications caused by carbonate dissolution. Water with RSC < 1.25 is safe for irrigation use. Those having RSC values from 1.25 to 2.5 are marginal and water with RSC > 2.5 is not suitable for use. The values of RSC of both ground and surface water of the study area in all the locations varied from -43 to -16.3 and -85.1 to -42 mg/l respectively. Therefore, water at all locations is safe for irrigation.

4) **Kelley's Ratio (KR)**

The ratio of sodium ion to calcium and magnesium ion as given by [3] is:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}\text{mg/l} \qquad (6)$$

The computed values for both ground and surface water samples of the study area ranged from 0.21 to 0.83 and 0.16 to 0.54 mg/l respectively, indicating the water is suitable for irrigation purpose as the value less than 1mg/l.

5) Magnesium Ratio (MR):

$$MR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \qquad (7)$$

Magnesium present in water would adversely affect the soil quality rendering it unfit for cultivation [16]. If MR is less than 50%, it can be safely used for irrigation. In the study area MR of both ground and surface water varied from 28.9 to 78.9 and 40 to 75.3mg/l respectively. This implies that locations12 and 21 of ground water are good for irrigation, whereas others are unsuitable. Only location 20 of surface water is good for irrigation, whereas the remaining locations are unsuitable (Table 5).

VI. CONCLUSIONS

Assessment of both ground and surface water of the study area for drinking and agricultural (irrigation) purposes was evaluated. Water analysis revealed that the samples were moderately hard to very hard in nature. Average concentrations of major cations and anions of ground water were in the order of Mg>Na>Ca>K>Cu>Fe>Pb and SO_4^{2-}>PO_4^{3-}>NO_3^->CO_3^{2-}>Cl>HCO_3^- while in surface water the order was of Mg>Ca>Na>K<Fe>Cu>Pb and SO_4^{2-}>PO_4^{3--}>NO_3^->CO_3^{2-}>Cl>HCO_3^- respectively. The study of water quality for drinking purpose indicated that most of the samples had low dissolved chemical load and was safe for drinking. Also, the present of Cu, Fe, Pb and CO_3 exceeded the permissible limit in some samples and required water treatment such as demineralization and water softening.

According to Piper (1944) diagram, three mixed water types were established (Ca-Mg-SO_4, Na-K-SO_4 and Ca-Mg-SO_4-Cl). Based on the values of SAR, SRC, Na%, EC and KR most of the water samples were acceptable for irrigation purpose. Conversely, only three locations from study area had their MR values suitable for irrigation, and others were unsuitable. Therefore, the study area needs water management plan. However, both the ground water and surface water were suitable for drinking and irrigation purposes in most part of the study area.

REFERENCES

[1] C. Ajibade (1982): The origin of the older granite of Nigeria, some evidence from the Zungeru region. Nigeria journal of mining and Geol., 19,223-230

[2] A. A. Elueze, J. O. Omidiran and M.E. Nton (2004): Hydrogeochemical investigation of surface water and ground water around Ibokun, Ilesha area, south western Nigeria. Journal of Mining and Geology, v.40(1), pp. (57-64).

[3] W. P. Kelley (1951): Alkali soils their formation properties and reclamation, Reinold publ. corp. New York.

[4] Ashwani Kumar Tiwari and Abhay Kumar Singh(2014): Hydrogeo-chemical investigation and ground water quality assessment of Pratapgarh district, Uttar Pradesh. Journal Geological society of india Vol. 83, pp. 329-343.

[5] Map of Niger State: Ministry of Land and Housing Minna (2012).

[6] P. McCurry (1976): The Geology of the Precambrian to lower Paleozoic rocks of Northern Nigeria, a review in Geology of Nigeria, edited by C.A. Kogbe, Elizabetan pub. Co. Lagos, pp.3

[7] M. J. Nematollah, P. Ebrahimi, M. Razmara and Ghasemi, A. Ghasemi (2016): Hydrogeo-chemical investigation and ground water quality assessment of Torbat –Zaveh plain, Khorasan Razavi, Iran. Journal on environ. Moni. Assess. (2016). 188:2. pp. 2-21.

[8] Rahane Prashant Bhausaheb and Dr. M. V. Jadhav (2016): The analysis of ground water quality status using linear regression method. International Journal of engineering Trends and Technology. Vol.38 (4)2231-5381

[9] N. Sawyer and McCarty, P. L. (1967): Chemistry for sanitary Engineers, IInd edition, McGraw Hill, New York, 518p.

[10] M. O. Oyawoye (1972): The basement complex of Nigeria, in African Geology, edited by T.F.J. Dessauragie and A.J. White man, Univ. Ibadan pp. 66-102.

A. M. Piper (1944): A graphical procedure in the geochemical interpretation of water analysis. Transactions American Geophysical Union, v.25, pp.914-928.

[11] W Russ (1957): The Geology of part of Niger, Zaria and Sokoto province, Geology survey of Nigeria bull. pp. 27.

A. K. Tripathi, U. K. Mishra, Mishra Ajay, Saras Tiwari and Dubey Parul (2012).Studies of Hydro-geochemical in Groundwater Quality around Chakghat area, Rewa District, Madhya Pradesh, India International Journal of Modern Engineering Research (IJMER) vol. 2, Issue 6 pp. 12-9 (2012).

[12] J. Desbarants, (2009): On elevated fluoride and boron concentrations in ground waters associated with the lake Saint-Martin impart structure, Manitoba. Applied Geochemistry, 24(5),915-927.

[13] U. S. Salinity laboratory staff (1954): Diagnosis and improvement of saline and alkali soils. U.S. Dept. Agriculture hand book. No. 60, pp. 160.

[14] T. L. Venugopal, M. Giridharam, Jayaprakash and P. Periakali (2009): Environmental impact assessment and seasonal variation study of ground water in the vicinity of river Adyar, Chennai, India. Environ. Monitor assessment 149:81-97.

[15] L. V. Wilcox (1955): Classification and use of irrigation water U.S. department of Agriculture cir. 969. Washington DC.

[16] World Health Organization (WHO) (2004): Guidelines for drinking water quality, incorporating 1 and 2 Agenda, v.1 Recommendation, Genera.

[17] S. A. Raji, F. O. Ijigade, O. Adelodun and O. A. Oyewole (2017): Using Aquifer test Pro 2016 for Estimating Ground water hydraulic parameter for sustainable yield. International Journal of Engineering Trends and Technology.Vol.48(2),2231-5381.

[18] A. Ambica, Saritha Banuraman and K. I layaraja (2012): An Assessement of Groundwater Quality and its parameters around Perungudi, the southern part of Chennai, India. International Journal of Engineering Trends and Technology. Vol. 3 issue 3 No. 3.