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The Soil and Water Quality of Waru Area (Fct), North Central, Nigeria

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ABSTRACT

Field mapping of Waru community of Abuja Municipal Area Council revealed four major rock types namely; Migmatite, Biotite gneiss, Granite gneiss and Anatectic granite. Twenty-two (22) water samples (stream, hand-dugs and boreholes) were collected for analysis using Atomic Absorption Spectroscopy. Heavy metals detected such as Chromium (Cr), Cadmium (Cd) and Lead (Pb) showed concentrations greater than the World Health Organisation (WHO) permitted limit in drinking water. Their concentration ranges are (0.046-0.236) mg/L, (0.034-0.121) mg/L and (0.003-0.023) mg/L, respectively. The high concentration of these metals (Cr, Cd and Pb) in water is purely supported by the high concentration of these elements in the soil samples, indicating a weathered product of the parents'rocks. Hydrochemical analysis also revealed two basic water types; Na-SO4 water type and Na-Mg-SO4 water type for the area, with their chemistry being controlled by ion exchange mechanism and by simple dissolution or mixing. Nemerow's Pollution Index was used to determine the contamination status of the area, the results showed some of the water samples are impure with respect to chromium, cadmium and lead concentrations. Contamination Factor also indicates a 'low contamination' for the area, while Pollution Load Index showed the area is unpolluted.

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1.0 INTRODUCTION

The information obtained through field mapping and petrographic analyses plays a significant role in characterizing the lithologic units identified in the area. Water quality is a growing concern throughout the developing world. Drinking water sources are under increasing threat from contamination, with far-reaching consequences for the health of people and for the economic and social development of communities and nations. Deteriorating water quality also threatens the Sustainable Development Goals number six (SDG's No 6) water target of having the proportion of people without sustainable access to safe water (Eze and Eze, 2018). Occasionally, pollution may derive from natural processes such as weathering and soil erosion. In the vast majority of cases, however, impairment of water quality is either directly or indirectly the result of human activities (Dix, 1981).

The nature of a pollutant and the quantity of it are important considerations in determining its environmental significance (UNDTCD, 1991). Generally, readily degradable substances are quickly broken down in the environment and are of great concern only when they are disposed off in sufficiently large quantities that a significant burden is placed on the natural purification processes (Walakira, 2011).

The Chemical contamination of water supplies both naturally occurring and from pollution is a very serious problem (Eze and Eze, 2018). As population, pollution and environmental degradation increases, so will the chemical contamination of the water supplies. This is due to a variety of factors, including population pressure, urbanization and the inadequate construction, operation and maintenance of water systems (Fewtrell, 2005).

Mason, (2002) defined pollution as "the introduction by man into the environment, of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure of amenity, or interference with legitimate uses of the environment". Pollutants are therefore chemical or physical in nature and can be measured more or less accurately in water.

The physical and chemical characteristics of water determine the quality in a particular area (Onoja, 2017). Collins *et al.,* (1989) however reported that waste can affect water, land or air qualities if proper practices of management are not followed, it can cause pollution of soil with chemical and the atmosphere with methane (a greenhouse gas) from decomposing waste. The measured quantities can then be compared with standards of allowable concentrations. Waste is a by-product of life. High standards of living and ever-increasing population have resulted in an increase in the quantity of waste generated (Sangodoyin and Agbawhe, 1992).

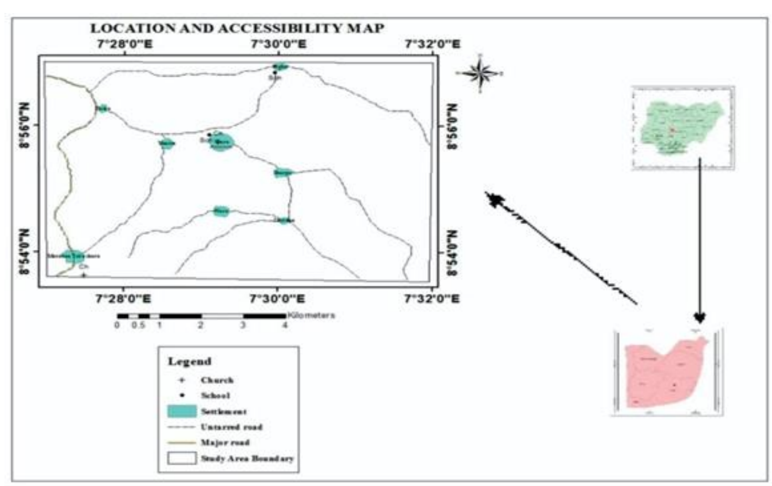

Figure 1.1: Location and Accessibility Map of Waru and its environs

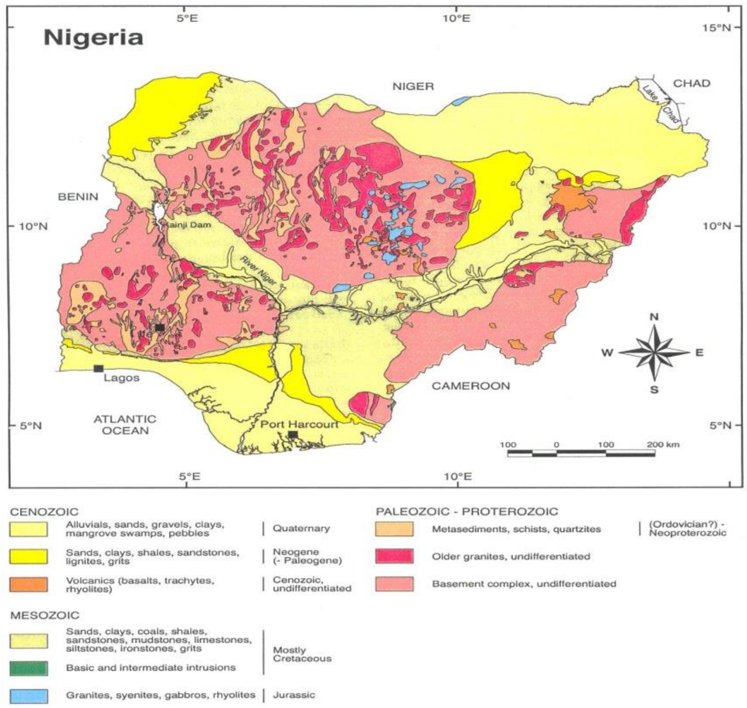

Figure 1.2: Generalized Geologic Map of Nigeria showing the study area in blue box (After Barr and Chase.,1974)

The study area is underlain by the Nigerian Basement Complex rocks of Precambrian age (Figure 2). Studies showed that the Nigerian Basement Complex rocks occur in the Mobile Zone of Pan-African reactivation between the West African Craton, to the west, and Congo Craton to the southeast (Grant, 1971; McCurry, 1976; and Ball, 1980). Radiometric ages obtained on different rock types using several radio chronometers shows that the Nigerian Basement Complex is polycyclic (Rahaman *et al.,*1983; Rahaman and Lancelot,1984).

The evidence of deformation in the rocks observed in the field also confirmed the polycyclic nature of this Basement Complex. It was generally agreed that the Pan-African orogeny and the associated plutonic phase which is approximately 600 million years have extensive influence on the rock characterization and deformational structures in the region (Grant, 1971; Trustwell and Cope, 1963; Oversby, 1975; Van Breemen *et al.,* 1975).
The underlying rocks of the Federal Capital Territory consist basically of Basement Complex and sedimentary rocks. The Basement Complex rocks made up of igneous and metamorphic rocks cover about 48% of the total area and in some places, the land is occupied by hills and dissected terrain (Mabogunje, 1977). The rocks consist mainly of schists, gneiss and older granite. The mountain ranges together with some isolated inselbergs are believed to have been poured out of volcanoes within the Tertiary period. The area underlain by the sedimentary rock covers about 52% of the total area of the Federal Capital Territory and largely constitute the undulating plains. These plains form present day remnants of erosional processes of the Quaternary period. Towards the south-west of the Federal Capital Territory, there exist sand ridges with outliers of sandstone capping.

Sandstone and clay also occur in significant proportions in parts of Abaji and Kwali Area Councils. These areas are easily dissected and indeed exhibit very glaring evidence of severe gully erosion (Balogun, 2001). Okechukwu (1974) and Kogbe (1978) also described the geology of the Federal Capital Territory as almost predominantly underlain by high grade metamorphic and igneous rocks of Precambrian age. These rocks consist of gneiss, migmatites, granites and schist belt outcrops along the eastern margin of the area. The belt broadens southwards and attains a maximum development to the south-eastern sector of the area where the topography is rugged and the relief is high. In general, the rocks in the Federal Capital Territory are highly sheared.

This study aimed at carrying out geological and environmental Assessment of Waru and its environs with the view to assess the water quality in the area.

2.0 MATERIALS AND METHODS

2 .1 Field Mapping and sample collection

The field investigation was carried out in two stages, first was a reconnaissance survey and geological field mapping was undertaken on a scale of 1:25,000. The geological field mapping was carried out with the help of a topographical map, geologic hammer, compass-clinometer and global positioning system (GPS). The mapping started by gridding the entire map both latitudinally and longitudinally. Points where samples were collected with the use of a Global Positioning System (GPS) noted. Their lithology, structure, mineralogy, texture, foliation and homogeneity were identified, measured and recorded. Field data measurements of strike and dip with compass-clinometer and recording of the co-ordinates of every sampling point using Global Positioning System (GPS) were also carried out. The rock samples collected during the geological field mapping were subjected to laboratory work which involved sample preparation, petrographic study and oxide analysis of major and trace elements in the rocks were carried out.

2.2 Ground and Surface water Sampling and Analysis

A total of twenty-two (22) water samples were systematically collected from hand-dug wells, boreholes, and stream in the study area. Clean 1.0 litre plastic containers were filled with water samples from each sampling location after rinsing it with the same water sample in each case. The filled plastics were immediately capped tight to prevent the trapping and/or absorption of atmospheric oxygen. Field tests and observations on the spot made include colour, pH, Electrical Conductivity (EC), Temperature and Total Dissolved Solids (TDS). To the samples for chemical analysis, drops of dilute nitric acid were added for preservation and to prevent cationic adsorption on the wall of the container during storage. The samples were adequately labelled, refrigerated and sent to the laboratory.

2.3 pH, Temperature, Electrical Conductivity, Total Dissolved Solids

The water samples were dissipated into beaker, and then calibrated, the probe of the musltimeter was inserted into the beaker. Each sample were read for the specific parameters that were taken as displayed on the LED display.
2.1.5 Test for Chloride, Nitrate, Phosphate, Sulphate, and Ammonia:
The machine was balanced to zero and then a pillow of the reagent for the test were added to the water sample in the cuvette and returned into the spectrophotometer. The values were recorded and the processes were repeated for the other reagents and tests.

3. GEOLOGY AND GEOCHEMISTRY

The study area Waru located in Abuja Municipal Area Council (AMAC) southern part of Abuja at latitudes 8˚54' 0'' N to 8˚56' 0'' N and longitude 7˚ 28' 0'' E to 7˚32' 0'' E part of Kuje Sheet 207 N.E and Keffi Sheet 208 N.W with an area of about 54.75km^2. The study area is almost predominantly an undulating terrain with an elevation gradient of around 70 m and a dendritic drainage pattern characterized the area.
According to the field relations and petrographic observation the rock in the study area were divided into four different types (Figure 3.1).

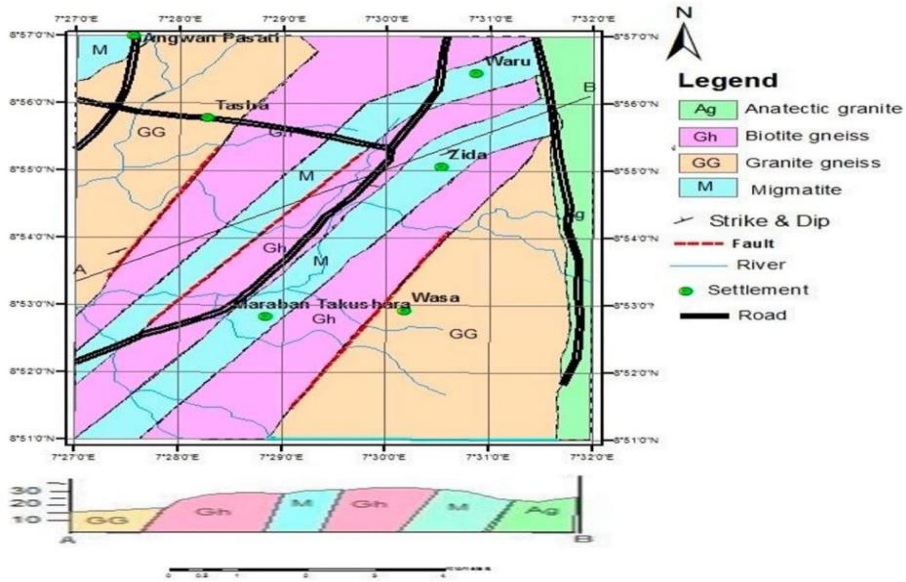

Figure 3.1 Geological map of Waru and it's surrounding environs.

The study area is underlain by the following rocks types migmatite, biotite gneiss, granite gneiss and anatectic granite. A lot of homogeneity of lithology and intricate relationship between them were identified and discussed. Contact relationships between the various rock types are commonly gradational.

3.1 Migmatite

The migmatites are medium grained in texture and occur both in the northwestern and southeastern part of the study area. It is believed to have been partially migmatized by the intrusion of acidic magma resulting into distinct felsic and mafic bands of few millimeters to tens of centimeters hence the name migmatite. The common structure observed in this rock is ptygmatitic folding and foliation. Also sets of NE-SW and NW-SE fractures and joints are common. Some of the joints were mapped cross-cutting each other showing that they were formed from different orogenic events.

3.2 Granite Gneiss

This rock occurs together with the biotite gneiss with transitional contacts between migmatite and biotite gneiss (Figure 4.1). Fractures and joints are the dominant structural features in this unit trending in NW-SE and NE-SW. Minor crosscutting quatzofedspathic veins were also observed. The field and hand specimen are shown in plate III. Thin section study of the rock showed that the major minerals present include quartz, biotite, plagioclase and microcline while accessory minerals present are apatite and opaque mineral.

3.3 Biotite Gneiss

Biotite gneiss is the most widespread rock type in the study area. Gradational contact of this rock with the granite gneiss has been established in the study area (Figure 4.1 and with field and hand specimen in Plates V and VI). The rock hosts quartzofeldspathic veins (felsic bands) and is mostly fresh outcrop. The structures found are joints, fractures and foliations. Most of these linear feature's trend in NE-SW and SE-NW directions. The major fractures represent important lines of weakness. The dominant structural features were developed during the Pan-African orogeny when the pre-existing structures were overprinted or obliterated (Adekoya *et al.,* 2012). The fracture controls the drainage system in the area.

3.4 Anatectic Granite

This rock occurs as leucocratic (pink) inequigranular in texture and shows evidence of granitization (Plate VIII). Outcrops of the rock are massive and are occasionally found together with biotite gneiss (Plate VIII). The joints and fractures in the rock trend mainly in the 138^{O} SE-NW. Quartz vein also occurred in the aplite at 09^{O}37'47.2" N, 003^{O}59'26.8" E. Both the aplite and the vein have trends of 072^{O} NE-SW. Quartz vein measured up to 20cm wide. These structural features occurred on all the rocks units.

3.5 Physical Parameters of Water

The physical parameters measured for the water samples include pH, temperature, electrical conductivity (EC) and total dissolved solids (TDS). The parameters and their values at each sampling point are given in Table 3.5. The range of values for pH in the study area is 5.48-8.11, and majority of these values are below the minimum drinking water permissible limit of 6.5-8.5 by WHO (2012), and NSDWQ (2007). The temperature range of (24-27) ^{OC} for the area shows only one sample with a value of (24^{O}C) less than the WHO minimum permissible limit of 25^{O}C for drinking water. The electrical conductivity range for the water in the area is (33-211) µS/cm, and all of these values are far below the NSDWQ (2007) permissible limit of 1000 µS/cm for drinking water. Table 3.5 gives the classification of groundwater on the basis of EC. The range of values of TDS in the area is 15-106. All of the TDS values for groundwater samples in Waru Abattoir and environs are far below the WHO (2012) permissible limit of 1000 mg/L. Tables 3.6 and 3.7 show the classification of groundwater based on TDS.

Table 3.1: Classification of groundwater samples on the basis of EC (US Salinity Laboratory, (Richards, 1954)

Salinity Hazard	EC (µS/cm)	No. of samples
Low	<250	11
Medium	250 – 750	0
High	750 – 2250	0
Very high	>2250	0
Total		11

Table 3.2: Groundwater Classification based on TDS (Davis and Dewiest, 1996)

TDS (mg/L)	Classification	Number of samples
<500	Desirable for drinking water	11
500 - 1000	Permissible for drinking water	0
1000 - 3000	Useful for irrigation water	0
>3000	Unfit for drinking and irrigation	0

Table 3.3: Groundwater Classification based on TDS (Freeze and Cherry, 1979)

TDS (mg/L)	Classification	Number of samples
<1000	Fresh water	11
1000 – 10000	Brackish water type	0
10000-100000	Saline water type	0
>100000	Brine water type	0
Total		11

Table 3.4: Physical Parameter Data for Groundwater Samples in Waru and surrounding areas

S/N	PH	TDS	TEMP	E.C
1	8.11	62	24	132
2	7.4	72	27	154
3	6.2	15	26	33
4	5.56	36	27	78
5	5.6	66	27	137
6	6.14	92	26	195
7	6.36	33	25	66
8	6.2	52	27	104
9	5.48	100	27	200
10	6.86	106	27	211
11	6.3	70	26	138
WHO (2012)	**8.5**	**600**	**25**	**3000**
NSDWQ (2007)	**8.5**	**500**		**1000**
SUM	**70.21**	**704**	**289**	**1448**
MEAN	**6.382727**	**64**	**26.27273**	**131.6364**
STDEV.	**0.805209**	**28.70888**	**1.00905**	**57.64941**
VARIANCE	**0.648362**	**824.2**	**1.018182**	**3323.455**
MINIMUM	**5.48**	**15**	**24**	**33**
MAXIMUM	**8.11**	**106**	**27**	**211**

3.6 Concentration of Cations and Anions in the Water Samples

The major cations and anions in the water samples analysed are Na, Ca, Mg, and NH_3, Cl, SO_4, NO_3 respectively. The concentration range for these cations are 11.51-19.63 mg/L for Na, 0.027-3.678 mg/L for Ca and 1.933-9.755 mg/L for Mg. The concentration range for the anions are 0.79-2.64 mg/L for NH_3, 1.00-2.56 mg/L for Cl, 66.00-151.00 mg/L for SO_4, and 4.00-9.00 mg/L for NO_3 respectively. The concentrations of these anions were used to plot the Durov, Piper and Schoeller diagrams. The concentrations of the ions are given in Table 3.5, Schoeller plot (Figure 3.2) shows the average chemical composition of the groundwater samples in the area. The relative trend for the cations shows that Na > Mg > Ca, and that of the anions shows that SO_4> HCO_3> Cl. The Piper plot (Figure 3.3) shows that majority of the water samples in the area plot in the Na+-K+-Cl-- SO_4 hydrochemical facie field (that is field G of the Piper plot). This indicates alkaline water with prevailing sulphate or chloride. Few of the water samples plot in the Ca+-Mg+-Cl—SO_4 - hydrochemical facie field (field E), indicating earth alkaline water with increased portions of alkalis with prevailing sulphate and chloride. The Durov plot (Figure 3.3) shows that the water samples collected for the study plot in fields 2 and 5, with majority of the samples plotting in field 2. Water samples in field 2 indicate an important ion exchange (with significant sodium ions). Samples in field 5 indicate fresh recent recharge water exhibiting simple dissolution or mixing (Gibbs plot 1970 shows the distribution of the water samples points in Waru and its environs by majorly in the central part of the plot. The central location of the water points shows the dominance of weathering of rocks in controlling the geochemistry of water in Waru and its environs).

Table 3.5: Major cations and anions in the water samples

S/N	Na	Ca	Mg	NH3	Cl	SO4	NO3
1	13.97	0.362	3.455	1.12	1.03	109	8
2	15.57	0.288	3.771	1.68	1.1	104	7
3	19.45	3.678	9.755	1.9	1.16	66	9
4	18.91	0.878	5.626	2.27	1.76	83	5
5	11.51	0.027	1.933	2.64	1.13	75	6
6	15.93	0.967	5.354	1.49	1	93	8
7	17.42	0.272	3.548	0.79	1.3	88	4
8	15.83	0.823	6.199	2.24	1.56	102	6
9	18.63	1.409	4.882	1.68	2	107	5
10	19.63	0.249	3.411	1.91	1	132	7
11	16.56	1.267	8.313	1.12	2.56	151	8
WHO (2012)	**200**	**150**	**50**	**3**	**250**	**250**	**50**
NSDWQ(2007)	**200**		**20**	**1**	**250**	**100**	**50**
SUM	**183.41**	**10.22**	**56.247**	**18.84**	**15.6**	**1110**	**73**
MEAN	**16.6736364**	**0.92909**	**5.11336**	**1.71273**	**1.41818**	**100.909**	**6.63636**
STDEV.	**2.49604596**	**1.01769**	**2.30977**	**0.5593**	**0.50444**	**24.5538**	**1.5667**
VARIANCE	**6.23024545**	**1.03569**	**5.33505**	**0.31282**	**0.25446**	**602.891**	**2.45455**
MINIMUM	**11.51**	**0.027**	**1.933**	**0.79**	**1**	**66**	**4**

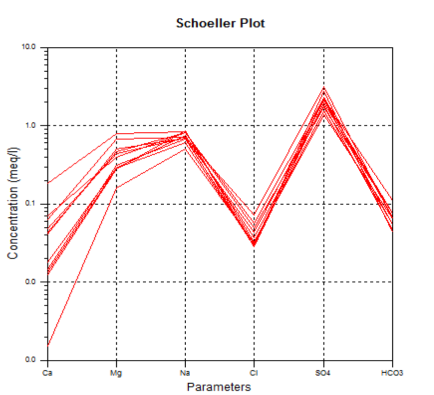

Figure 3.2: Schoeller plot of groundwater.

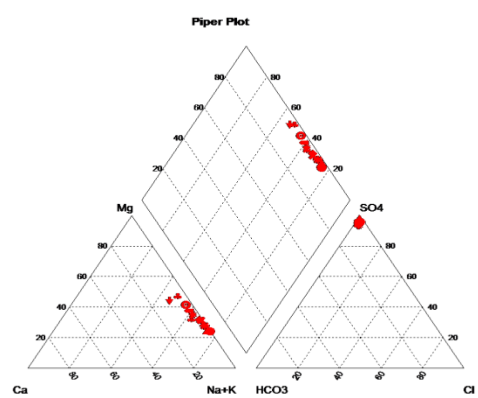

Figure 3.3: Piper plot of hydrochemical facies

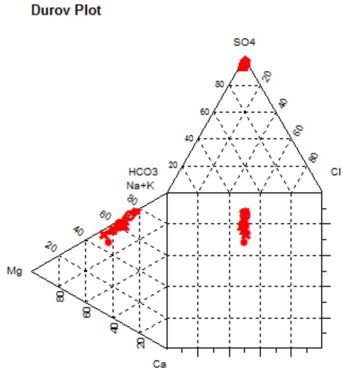

Figure 3.4: Durov plot of major ions in the water samples.

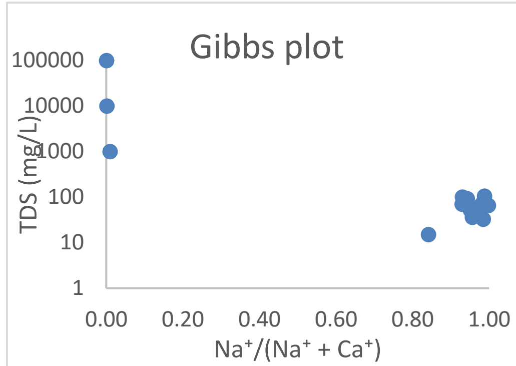

Figure 3.5: Gibbs Plot

Gibbs (1970) plot shown in the Figure 3.5 shows the distribution of the water sample points in Waru and its environs by majorly in the central part of the plot. The central location of the water points shows the dominance weathering of rocks in controlling the geochemistry of water in Waru and its environs.

3.7 Heavy Metals Concentration in the Area

The geochemical analysis of the water samples revealed the major heavy metals in the area include Mn, Cr, Cd, Fe, Zn, Cu and Pb. The concentrations range (in mg/L) for these heavy metals are 0.014-0.135 for Mn, 0.046-0.236 for Cr, 0.034-0.121 for Cd, 0.004-0.121 for Fe, 0.026-0.257 for Zn, 0.006-0.037 for Cu and 0.003-0.023 for Pb. Table 3.6 gives the concentrations of heavy metals in the study area, and Table 3.7 gives the water parameters and their permissible limits (based on WHO, 2012 and NSDWQ, 2007 standards).

Table 3.6: Heavy Metals Concentration in the area

S/N	Mn	Cr	Cd	Fe	Zn	Cu	Pb
1	0.055	0.046	0.096	0.121	0.026	0.009	0.005
2	0.08	0.179	0.087	0.018	0.043	0.006	0.006
3	0.129	0.114	0.041	0.013	0.121	0.012	0.007
4	0.014	0.054	0.067	0.007	0.075	0.023	0.009
5	0.031	0.077	0.063	0.022	0.041	0.013	0.003
6	0.099	0.095	0.04	0.04	0.062	0.037	0.017
7	0.053	0.049	0.079	0.015	0.079	0.037	0.023
8	0.032	0.048	0.121	0.004	0.257	0.007	0.007
9	0.045	0.075	0.034	0.005	0.039	0.007	0.019
10	0.033	0.236	0.053	0.019	0.038	0.013	0.003
11	0.135	0.077	0.115	0.006	0.092	0.009	0.004
SUM	**0.706**	**1.05**	**0.796**	**0.27**	**0.873**	**0.173**	**0.103**
Maximum	**0.135**	**0.236**	**0.121**	**0.121**	**0.257**	**0.037**	**0.023**
Minimum	**0.014**	**0.046**	**0.034**	**0.004**	**0.026**	**0.006**	**0.003**
Mean	**0.03715789**	**0.05526**	**0.04189**	**0.01421**	**0.04595**	**0.00911**	**0.00542**

Stdv	**0.0410897**	**0.06062**	**0.02999**	**0.03362**	**0.06538**	**0.01151**	**0.00699**
WHO(2012)	0.4	0.05	0.003	0.3	5	1	0.01
NSDWQ(2007)	0.2	0.05	0.003	0.3	3	1	0.01

Table 3.7: Standards for drinking water (maximum permitted limit, in mg/L) and health impact

S/N	Parameter	NSDWQ (2007)	WHO (2018)	Health impact (SON, 2007)
1.	Aluminium	0.2	0.2	Potential neuro-degenerative disorders
2.	Arsenic	0.01	0.01	Cancer
3.	Barium	0.7	0.7	Hypertension
4.	Cadmium	0.003	0.003	Toxic to the kidney
5.	Chloride	250	250	None
6.	Chromium	0.05	0.05	Cancer
7.	Conductivity	1000µS/cm	2500µS/cm	None
8.	Copper	1	2.0	Gastro-intestinal disorder
9.	Hardness(as$CaCO_3$).	150	500	None
10.	Iron	0.3	0.3	None
11.	Lead	0.01	0.01	Cancer, toxic to central nervous system, affects mental development in infants and interferes with vitamin D metabolism.
12.	Magnesium	0.20	None specified	Consumer acceptability
13.	Manganese	0.2	0.4	Neurological disorder
14.	Mercury	0.001	0.006	Affects the kidney and central nervous system
15.	Nickel	0.02	0.07	Possible carcinogenic
16.	Nitrate	50	50	Cyanosis and asphyxia
17.	pH	6.5-8.5	8.5	None
18.	Sodium	200	200	None
19.	TDS	500	1000	None
20.	Sulphate	100	250	None
21.	Zinc	3	5	None
22.	Calcium	-	150	
23.	Temperature (^{O}C)	-	25	
24.	Potassium	-	10	
25.	Selenium	-	0.04	

3.8 Contamination status of water in the area

The concentrations of the heavy metals were used to determine the contamination status of groundwater in the area. This was done using pollution/contamination indices such as contamination factor (CF), pollution load index (PLI) and Nemerow's pollution index (NPI). The results of these analyses were tabulated and given in Tables 3.8, 3.9 and 3.10.

Table 3.8: Contamination Factor (CF) of Heavy Metals in the water samples

S/N	Mn	Cr	Cd	Fe	Zn	Cu	Pb
1	0.000119826	0.000645	0.32	0.025636	0.000275	0.00033	0.000168
2	0.000174292	0.002511	0.29	0.003814	0.000456	0.00022	0.000202
3	0.000281046	0.001599	0.136667	0.002754	0.001282	0.00044	0.000236
4	3.05011E-05	0.000757	0.223333	0.001483	0.000794	0.000842	0.000303
5	6.75381E-05	0.00108	0.21	0.004661	0.000434	0.000476	0.000101
6	0.000215686	0.001332	0.133333	0.008475	0.000657	0.001355	0.000572
7	0.000115468	0.000687	0.263333	0.003178	0.000837	0.001355	0.000774
8	6.97168E-05	0.000673	0.403333	0.000847	0.002722	0.000256	0.000236
9	9.80392E-05	0.001052	0.113333	0.001059	0.000413	0.000256	0.00064
10	7.18954E-05	0.00331	0.176667	0.004025	0.000403	0.000476	0.000101
11	0.000294118	0.00108	0.383333	0.001271	0.000975	0.00033	0.000135
SUM	**0.0015381**	**0.01473**	**2.65333**	**0.0572**	**0.00925**	**0.00634**	**0.00347**
Maximum	**0.0002941**	**0.00331**	**0.40333**	**0.02564**	**0.00272**	**0.00136**	**0.00077**
Minimum	**3.05E-05**	**0.00065**	**0.11333**	**0.00085**	**0.00028**	**0.00022**	**0.0001**
Mean	**8.095E-05**	**0.00078**	**0.13965**	**0.00301**	**0.00049**	**0.00033**	**0.00018**
Stdv	**8.952E-05**	**0.00085**	**0.09997**	**0.00712**	**0.00069**	**0.00042**	**0.00024**
Product	**4.35225E-44**	**4.91E-33**	**6.47E-08**	**2.3E-28**	**1.35E-35**	**2.42E-37**	**2.23E-40**

Table 3.9: Pollution Load Index (PLI) of Heavy Metals in the water samples

S/N	PLI
1	0.001374
2	0.001376
3	0.00155
4	0.001058
5	0.001052
6	0.002062
7	0.001776
8	0.001141
9	0.000969
10	0.001177
11	0.001303

Table 3.10: Nemerow's Pollution Index (NPI) of Heavy Metals in the water samples

S/N	Mn	Cd	Cr	Cu	Fe	Pb	Zn
1	0.1375	32	0.92	0.009	0.403333	0.5	0.0052
2	0.2	29	3.58	0.006	0.06	0.6	0.0086
3	0.3225	13.66667	2.28	0.012	0.043333	0.7	0.0242
4	0.035	22.33333	1.08	0.023	0.023333	0.9	0.015
5	0.0775	21	1.54	0.013	0.073333	0.3	0.0082
6	0.2475	13.33333	1.9	0.037	0.133333	1.7	0.0124
7	0.1325	26.33333	0.98	0.037	0.05	2.3	0.0158
8	0.08	40.33333	0.96	0.007	0.013333	0.7	0.0514
9	0.1125	11.33333	1.5	0.007	0.016667	1.9	0.0078
10	0.0825	17.66667	4.72	0.013	0.063333	0.3	0.0076
11	0.3375	38.33333	1.54	0.009	0.02	0.4	0.0184
SUM	1.765	265.3333	21	0.173	0.9	10.3	0.1746
Maximum	0.3375	40.33333	4.72	0.037	0.403333	2.3	0.0514
Minimum	0.035	11.33333	0.92	0.006	0.013333	0.3	0.0052
Mean	0.092895	13.96491	1.105263	0.009105	0.047368	0.542105	0.009189
Stdv.	0.102724	9.996969	1.212448	0.011507	0.112065	0.69896	0.013077

4.DISCUSSION OF FINDINGS

The results of the geochemical analysis of the soil samples showed chromium content is high in most of the samples. This may be the reason for the high chromium content in most of the water samples to the point of being deemed 'impure' by Nemerow's Pollution Index (NPI) value. The arsenic, lead and barium concentrations are found to be high also in most of the rock samples. This may account, also, for the high lead content in some of the water samples. The heavy metals clustered column charts show the range of concentrations for Manganese in the water samples of the area is (0.014-0.135) w%, while that of chromium and cadmium are (0.046-0.236) w% and (0.034-0.121) w%, respectively.

The concentration range for Iron, Zinc, Copper and Lead are (0.004-0.121) w%, (0.026-0.257) w%, (0.006-0.037) w% and (0.003-0.023) w% respectively.

The contamination Indices calculated shows that samples 6, 7 and 9 have Nemerow's Pollution Index (NPI) values for Lead greater than unity (1). This indicates they are impure and remedial measures have to be taken to make them safe for drinking, with respect to Lead.

Other than samples 1, 7 and 8, all the other samples have NPI values for chromium greater than unity (1), meaning they are impure (with respect to chromium content).

All the water samples show NPI values for cadmium far greater than one (1). As such, they are impure, on the basis of cadmium content, and the water need to be treated to make them safe for drinking. Contamination Factors (CF) calculated for all the sampling sites give values less than one (1), indicating the area has 'low contamination'.

The Pollution Load Index (PLI) calculated for all the sampling sites have values less than one (1), indicating 'unpolluted' level for the area. From the Gibbs plot, Rock-weathering is responsible for the chemistry of the water in Waru, and the surrounding areas.

The hydrochemical analysis revealed two water types namely Na-SO_4 water type; and Na-Mg-SO_4 water type as obtained from Piper plot. While in the Durov plot the water samples in the area are with significant sodium ions, an important ion exchange is presumed. Samples which plot indicate fresh recent recharge water exhibiting simple dissolution or mixing. The Schoeller plot shows the trend for cations is Na > Mg > Ca, while the anions show SO_4> HCO_3> Cl.

5. CONCLUSION:

The water samples showed that nine (9) of the samples are slightly acidic (5.48-6.86) while the remaining two are slightly alkaline (7.4 and 8.11). Hydrochemical analysis showed two basic water types in the area (Na-SO4 water type and Na-Mg-SO4 water type), with the chemistry of the water types being governed by ion exchange and simple dissolution or mixing. The relative trend of major cations and anions are Na > Mg > Ca and SO4 > HCO3 >Cl, respectively.

In some of the water samples, chromium, cadmium and Lead showed concentrations greater than the level permitted by WHO (2012), and NSDWQ (2007) in drinking water.

Nemerow's Pollution Index indicated some of the water samples are impure, with respect to their chromium, cadmium and Lead concentrations. Contamination Factor calculated indicates the area has 'low contamination', and the Pollution Load Index showed the area is 'unpolluted'. Gibbs plot indicates that the water geochemistry is as a result of weathering of the rock in the area lending its character to the properties of the water in Waru and its surrounding areas.

The concentrations of the heavy metals showed chromium, cadmium and Lead having concentrations in some of the samples to be higher than the NSDWQ, (2007) permissible limits for drinking water.

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