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Impact of chemical weathering on groundwater chemistry of Abeokuta area, SW-Nigeria

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ABSTRACT

This study involved assessment of effect of chemical weathering of bedrock on the hydrochemical character of associated shallow groundwater system in Abeokuta area, SW-Nigeria. Physico-chemical parameter revealed a mild acidic water system with pH of 5.9–6.9 while the hydrochemical analyses revealed the order of abundance of elements concentrations as $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ for cations and $HCO_3>Cl>SO_4>NO_3$ for anions in Migmatite Gneiss (MG) compared to the concentration order of $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ for cations and $Cl>HCO_3>SO_4>NO_3$ for anions under Porphyritic Biotite Granite (PBG) and Porphyroblastic Gneiss (PG) bedrock settings. Further hydrochemical characterization revealed that the water samples collected around the PBG and PG were mostly of $Ca\text{-}HCO_3$ water type, characterized with low total dissolved solids (TDS) of 228–391mg/l while those around MG revealed $Na\text{-}HCO_3$ water type with TDS of about 315mg/l. A comparison of the dissolved trace elements revealed that the water samples from the three bedrock settings revealed concentrations within the limits of WHO/EU standards except for enrichment of Al and Fe with concentrations of 0.25–0.55mg/l and 0.36–0.60mg/l respectively. This is a clear indication of geogenic influence of water-rock interactions on shallow groundwater chemistry.

Introduction

The tropical areas of the world are noted for high rate of bedrock weathering arising from the effect of abundant rainfall and all year round sunshine. The rate and nature of chemical weathering are often govern by many variables such as parent rock type, topography, climate, leaching conditions and biological activity (Green et.al. 2006). Also chemical weathering helps in the mobilization and redistribution of major and trace elements in the environments through effect of various processes such as dissolution of primary minerals, formation of secondary phases, co- precipitation and ion exchange. However, nature strikes balances in the concentration of metals and metalloids released from weathered bedrock resulting in distinct chemical characteristics of the corresponding derived soil and associated subsurface groundwater. In addition, human activities coupled with the usages of industrial and manufactured products have been regarded as the main sources of heavy metals released into the environment.

Consequently, surface soil and subsurface weathered profiles do serve as the sink for these geogenic and anthropogenic trace and heavy metals while the subsequent release of these metals, under the influence of tropical monsoon rain, through dissolution and vertical leaching process is of serious environmental concerns. Thus, the attendant soil and shallow groundwater contaminations with respect to toxic trace/heavy metals often pose environmental and human health problems and thus attract the attention of researchers from a wide range of disciplines (Islam et.al, 2002; Nesbitt and Young, 1982; Green et.al, 2006; Tijani et.al, 2005). Therefore, for better understanding of dynamics of the metal release into the environmental media (soils and waters). It should be noted that while most people probably associate metal rich soils with hazardous waste contamination, there are many cases where soils, rocks and waters are naturally enriched in metals or trace metals. Hence, there is the need for better understanding of the weathering induced geogenic release of metals.

On the basis of the above background, this study assess the weathering-induced elemental release of metals under a weathered basement rock setting and attendant impacts on the chemical quality of associated shallow groundwater system in Abeokuta area, SW-Nigeria. A number of previous studies on the weathered rock profiles of the Basement rocks of SW-Nigeria, especially around Abeokuta (Bolarinwa et. al. 2004, Elueze et.al. 2004, Tijani et al., 2005) are in most cases focused separately either on water or weathered rock units while this study highlights the water-rock interactions and impacts of the elemental release on groundwater chemistry through the in-situ weathered bedrock. The justification for this lies in the importance of weathered basement regolith as primary groundwater aquifer for domestic water supply. Hence the need for assessment of the influence of the weathering induced metal release on the chemical characteristics of the groundwater system as geogenic control to serve as guide in monitoring of groundwater quality in respect of anthropogenic contaminations.

Geographical and Geological Setting. The area of study is situated about 70km north of Lagos and lies between latitude 7^{O} 07` and $7^{O}$ 12`N and longitude 003^{O} 16` and $003^{O}$ 24`E. This covers about 30km wide. The area is located in a hummocky terrain with a well pronounced undulating topography with prominent hills characterized by steep slope varying in altitude

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between 30m and 180m above sea level. The study area falls on the Precambrian basement complex rocks of southwestern Nigeria which is part of the Nigerian basement complex terrain and the Dahomey basin sedimentary rocks. The basement complex of southwestern Nigeria lies to the east of West African Craton in the region of late Precambrian to early Paleozoic Orogeny (Rahman, 1976). The Nigerian basement complex extends westwards and is continuous with the Dahomeyan of the Dahomey–Togo-Ghana region. To the east and the south the basement complex is covered by the Mesozoic-Recent sediments of the Dahomey and Niger Delta basins. The geology of Abeokuta area consists predominantly of the basement rocks and sedimentary rocks (Figure 1).

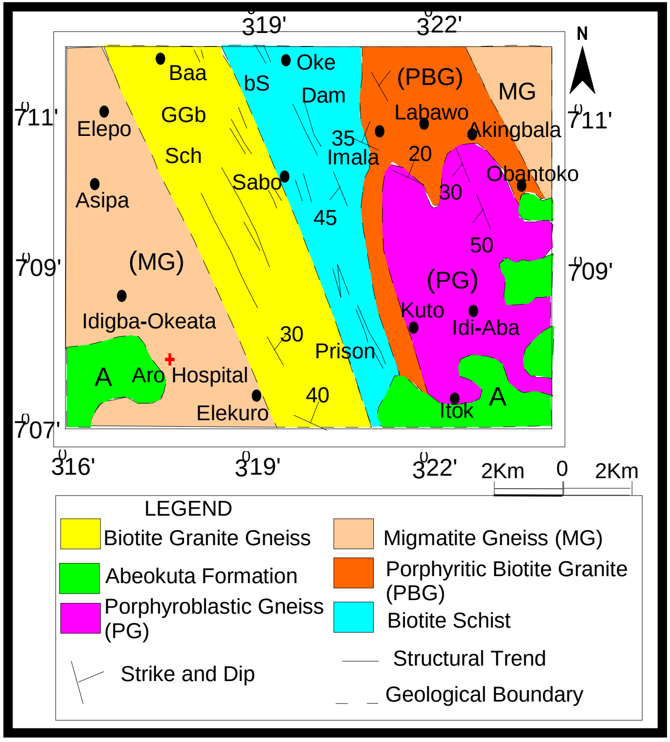

Figure 1: Geological map of Abeokuta area with sampled rock types abbreviated in bracket

Methodology

Nineteen weathered soil profiles from three bedrock settings were identified, observed and sampled. The observations were done at different horizons to identify the individual characteristics of the soil and sampling was done at the different horizons of the profile. To achieve a balanced representation that can be used for comparison, two separate soils profile sections each from the three bedrock settings were selected for laboratory analysis. The profile sections were identified as PBG, PG and MG respectively. The soil horizons were distinguished by their label as A1, B1, C1 and A2, B2, C2 for the two sections in each rock type. However, two horizons were identified for the second profile of PBG. Also, the method followed in sampling these horizons are:

Horizon A	Top Soil
Horizon B	Weathered Unit
Horizon C	Saprolite/Saprock
Horizon D	Fresh bedrock

Likewise, 30 groundwater samples obtained from shallow unconfined hand dug wells (<25m) tapping around each weathered section were collected. These were 8, 12 and 10 water samples for PBG, PG and MG respectively and they were analyzed for both physical and chemical parameters. The physical parameters include total dissolved solids (TDS), pH, electrical conductivities (E.C) and temperature. These parameters were determined on spot in the field by using Petra500 multi-parameter analysers. Also, extra attention was paid to the turbidity, elevation, well surface to peizometric level and bottom. The water samples were collected and stored in two sterilized crystal bottles. One bottle was acidified with concentrated HCl acid and analysed for groundwater cation while the other bottle was analysed for anion. The ionic balances for the analyses of water samples varied from -4.0% to 5.2%. The sampling followed the guidelines of ASTM D 5730. The technique employed in the soil analyzed was inductively coupled plasma/atomic emission spectrometry analysis (ICPE-9000) machine brand following a Lithium metaborate/tetraborate fusion and dilute nitric digestion. Losses on ignition (LOI) were determined by weight differences after ignition at 1000°C. While the cation present in groundwater were detected by ICP-MS method to obtain a more precise data for metals present in solution, samples were diluted to below 0.1% in order to increase the accuracy of result. However, titrimetric method was used in the analysis of the anion present in the groundwater.

Results And Discussions

Chemical Weathering Analysis

The major chemical composition of the analysed soil revealed SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, TiO_2, P_2O_5, MnO, Cr_2O_3 as major oxides presented in Table 1. Results showed that the saprock, weathered unit and topsoil were dominantly rich in silica, alumina and iron oxide in the three rock types. These three oxides constitute about 70-75% of the rock and soil. Their values show a general weathering trend, were Fe_2O_3 is enriched at the topsoil and depleted around weathered unit and saprolite while Al_2O_3 enrichment increases from the topsoil down the profile with the silica behaving in similar manner (Table 1). Furthermore, scattered plot of %SiO_2 versus %LOI (Figure 2) showed a correlation values (r = 0.81, 0.78, 0.58) for the PBG, PG and MG respectively. The relatively high correlation values of PBG and PG support weathering increase with the enrichment of silica and depletion of water in the soil. This further confirms the laboratory geochemical results data to the prominence of quartz grains as the remains of weathering processes. Moreso, as water depletion occur in the rock, the weathering intensity increases more around the granite and gneiss than the migmatite. It is summarised that the low amounts of other major rock forming elements present in the geochemical soil results confirms the impact of weathering processes.

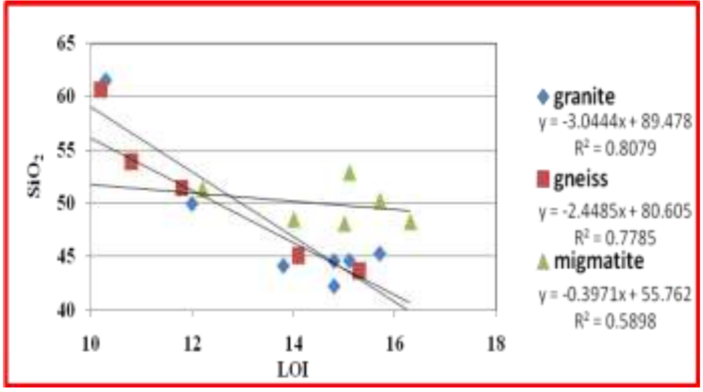

Figure 2: Cross plots of SiO_2 vs LOI

However, Chemical Index of Alteration, *{100(Al_2O_3/ (Al_2O_3+CaO+Na_2O_3+K_2O))}*, a measure used to determine the extent of chemical weathering of rock to soil, formulated by

Nesbitt and Young (1982) categorize soil from 0-100. Values closer to 100 have high impact of chemical weathering on rocks thus altering primary minerals formed during rock formations into different secondary minerals. 90% of the rocks and soil samples analysed in this work had values closer to the optimum weathering values of 100. These values demonstrate the influence of weathering processes through the enrichment of weathering resistant silica and depletion of Fe, Al and water along the soil horizons.

Hydrochemical Analysis

Water is known to be a universal solvent. The mobility of water makes its an excellent exploration tool. As water moves through weathered bedrock major changes occur in is chemical composition. A schoeller plot of the chemical analysis employed to determine the chemical character dominant in the groundwater and water type of representative samples around each weathered section was calculated in milliequivalent per litre (meq/l) and from the plot we can decipher the dominant cations and anions to know the water type in the study area.

The groundwater pH around PBG ranges from 5.1–6.7 with a mean pH of 5.9 indicating a mildly acidic water and a mean electrical conductivity value of 303.7µs/cm. Dominant anions include bicarbonate and chloride with a mean value of 0.66meq/l and 1.21meq/l and that of SO_4^{2-} and NO_3^- are 0.54meq/l and 0.24meq/l respectively, PG record highest mean electrical conductivity value of 521µs/cm with pH range of 5.9-7.0 and a mean value of 6.4 indicating slightly acidic waters. The TDS values ranges from 129mg/l to 850mg/l with mean of 391mg/l. Dominant anions include bicarbonate and Chloride with mean value of 1.87meq/l, 2.03meq/l and SO_4^{2-} of 0.80meq/l and NO_{3-} of 0.14meq/l. While shallow groundwater samples around the MG rock type, reveal E.C with slightly high mean of 419µs/cm, a pH that ranges from 6.7-7.3 with an average of 6.9 indicate a slightly acidic to slightly alkaline water, but the TDS values of 126-525mg/l and an average of 315mg/l was recorded for the groundwater. Considering their dominant anions, bicarbonate elements dominate with mean value of 1.64meq/l while Cl^-, SO_4^{2-} and NO_3^- are 1.24meq/l, 0.76meq/l and 0.36meq/l respectively.

The hydrochemical analysis revealed the general order of abundance of elements as reflected by their mean concentration values as $HCO_3>Cl>SO_4>NO_3$ for anion and $Na^+>Ca^+>Mg^{2+}>K^+$ for cation in Migmatite Gneiss which differs from Porphyritic Biotite Granite and Porphyroblastic Gneiss anion order of $Cl>HCO_3>SO_4>NO_3$ and cation order of $Na^+>Ca^+>Mg^{2+}>K^+$.

Further analysis delineates a Ca-HCO_3 water type for the 8 and 10 water samples collected around the Porphyritic Biotite Granite and Porphyroblastic Gneiss respectively (Figure 5 and 6). This is characterized with low total dissolve solid ranging from 139-367mg/l with average value of 228 mg/l for the Porphyritic Biotite Granite and a range of 129-850mg/l with average value of 391mg/l for the Porphyroblastic Gneiss. While Migmatite has TDS values range of 126-525mg/l and average of 315mg/l (Table 2).

These low TDS status permits the classification of groundwater in the study area as freshwater (Domenico and Schwartz, 1998).

However water type sample around the Migmatite Gneiss profile were characterized by both Ca-HCO_3 and Na-HCO_3 water type (Figure 7). The combination of these two water types suggest a possible cation exchange process which leads to the evolution of Ca-HCO_3 to Na-HCO_3 water type. Within this hydrochemical system, there are more HCO_3 ions than Ca^{2+} and Mg^{2+} ions in equivalent concentrations. Hence the excess HCO_3 get involved in the exchange reactions with Na^+ available in the system.

Also, Ca-HCO_3 water type indicate areas of fresh recharge (Olobaniyi et.al. 2007) and may originate from CO_2-charge rainstorm which produce weak carbonic acid that later dissociates into hydrogen ions and bicarbonate ions (Tijani et.al. 2003). The cation exchange process effectively increased Na^+ concentrations at the expense of Ca^{2+} and $Mg^{2+.}$ Therefore, excess metals find their way into the environment.

Trace Metals in Groundwater

The comparison of the trace elements found in groundwater samples from the shallow unconfined aquifers with the recommended WHO/EU standard shows that Al and Fe are in excess with a value of 0.25mg/l for the Al and 0.36mg/l for Fe in the MG and a value of 0.4mg/l for Al and 0.48mg/l for Fe in the PG and a value of 0.55mg/l for Al and 0.6mg/l for Fe in the PBG.

The enrichment of Fe can be attributed to the chemical weathering of mafic minerals such as biotite pyroxene, hornblende and amphibole dominating the mineralogical composition of the bedrock that serve as aquifers for shallow groundwater systems in the Abeokuta area and also due to the tropical climatic situation with rainfall above 1200mm and abundant sunshine leading to oxidation and ferruginization of Fe-bearing minerals.

Other sources of Fe may be derived from solid phase rock minerals i.e acidic groundwater attack on iron enriched rocks such as goethite and hematite found to be common on rocks of southwestern Nigeria (Elueze, 2004).

However, enrichment of Al can be attributed to the weathering/alteration of feldspar to clay minerals (kaolin) and dissolution or leaching of Al by infiltrating acid rain/ recharge water into the shallow groundwater system. Langmuir (1997) pointed out that natural water having pH values between 4.5 and 7 produces weak carbonic acids and small amount of organic acids such as the fulvic acids.

Likewise, manganese in PG of value 0.1mg/l and PBG of 0.16mg/l are above the EU standard of 0.05mg/l (Table 3). Mafic minerals such as Fe and Mn in soils/rocks become soluble in increasingly acidic and/or anaerobic conditions.

Since both Fe and Mn occur together in rocks, it is possible for them to be released and leached into shallow groundwater wells especially under increasing acidic pH as with the case of PBG rocks. Reducing conditions affecting rocks combined with the attack of moderate acidic groundwater on minerals within igneous rocks most especially hornblendes led to the dissolution of manganese.

Generally, the quantity of trace metals present in the groundwater is low compared with the WHO/EU standard this may have resulted from the low pH (Table 3) where most natural groundwater are mobile and the mass occur as charged metal ion which reach equilibrium with the solid phase usually a metal-hydroxide, metal-carbonate or metal sulphide (Domenico and Schwartz, 1998). Table 2 contains WHO/ EU drinking water standard comparative table in accordance with the trace element found in the water sample. The EU standards are more recent (1998), but not as complete and strict as the WHO standards (1993)

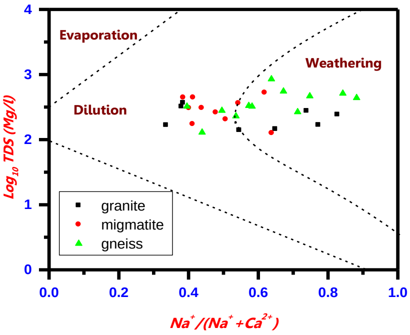

Figure 4: Gibbs diagram of weathering and dissolution of minerals

A commonly used diagram based on the plotting of Gibbs (1970) diagram (Figure 4) where $\log_{10}$TDS values against the ratio of Na^+/ ($Na^+ + Ca^{2+}$) were used to determine the geochemical process dominant in the groundwater.

The PBG and PG samples fall within the weathering zone while those of migmatite samples fall within the dilution zone. In general, all the plotted samples fall within the dilution-weathering range and this means that chemical weathering was responsible for the chemical character displayed by the granitic and gneissic rock on one hand and dissolution/dilution effect of the mineralogical constituent of migmatite rocks on the other. Weathering effect was aided by the abundant rainfall experienced yearly in the study area which ensures a continuous leaching of the sediment thereby reducing it soluble component with time.

These combine with dilution of groundwater resulting from abundant recharge by precipitation and continuous weatherability status of the soil allowing seepages into the aquifer. This diagram further buttresses the fact that the weathering, dissolution and dilution effect are responsible for the chemical character of shallow groundwater system present in the study area

Implication for rural water supply option

Groundwater is one of the natural resources tapped by man, animals and plants to meet their needs for life sustenance. Groundwater acidity promotes the mobilization of trace metals into groundwater systems. The trace metal load is generally low in the groundwater, perhaps due to the low trace metal load of the host rocks.

However, the enrichment of Al, Mn and Fe into the groundwater relatively affects the water quality for local consumption. Increasing iron result in primary aesthetic problem because they colour water on exposure to air, they may also create sensory problems, impart taste and odour (USEPA, 1992). The groundwater of Abeokuta area contains iron far in excess of the WHO standard most especially around areas situated on bedrock of granite and gneisses. However, the concentrations of iron found in most drinking water, is not considered a health problem, even; iron can be of health benefit. Small concentrations are essential to human health because iron helps transport oxygen (O_2) in the blood (USEPA, 1992). Also Mn intake from drinking water is usually lower than intake from food. Though essential element excessive Mn can affect neurological functions. On exposure to air, manganous ion is oxidized to hydrated oxides causing staining of laundry/utensils and encouraging the growth of bacteria.

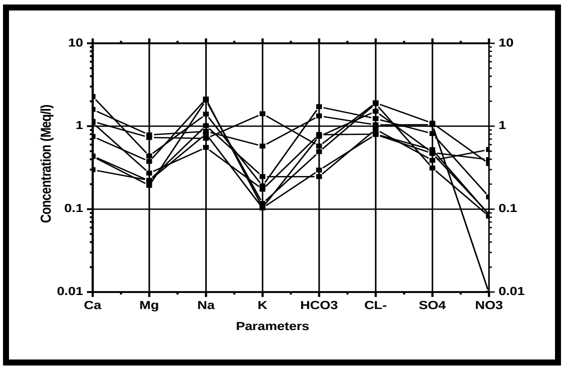

Figure 5: Schoeller diagram for the PBG

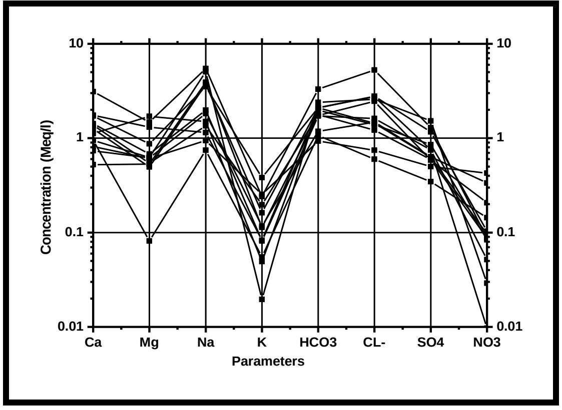

Figure 6: Schoeller diagram for the PG

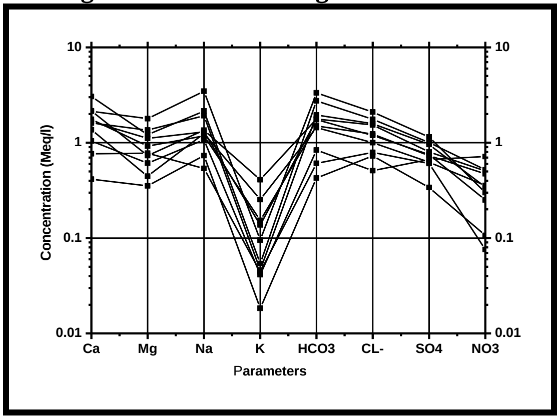

Figure 7: Schoeller diagram for the MG

Conclusion

The hydrochemical assessment of Abeokuta shallow groundwater has revealed the impact of chemical weathering of bedrock on the chemical characteristics of shallow groundwater system in the area. The effect is due to factors such as the bedrock type present in the area, topography, climatic condition and more importantly the water-rock interaction. Chemical weathering is responsible for chemical characteristics displayed by the shallow groundwater than anthropogenic impacts. Water type's presents are Ca-HCO_3 and Na-HCO_3-Ca-HCO_3. These water types are common within groundwater of basement complex rocks (Abimbola and Tijani, 1999). The shallow groundwaters are under saturated with respect to Sulphate and Nitrates and these were supported by the low TDS and/ Conductivity values. Since majority of inhabitant in the area rely absolutely on shallow groundwater for water supply option, the water can be qualified as fit for domestic and agricultural usage but must be treated for metals such as Fe, Al and Mn for drinking purposes. These metals have greatly contaminated the shallow groundwater system and further confirmed geogenic impact on hydrochemistry of shallow groundwater system.

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Table 1: Major elemental chemical analysis of the three rock types and their weathering products in (%)

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	LOI	Sum	CIA
	%	%	%	%	%	%	%	%	%	%	%	%	%	
PBGA1	42.28	30.22	10.79	0.17	0.05	0.03	0.76	0.62	0.07	0.01	0.007	14.8	99.92	97.30
PBGB1	45.32	36.98	1.26	0.13	0.01	0.01	0.63	0.03	0.01	0.01	0.002	15.7	100	98.27
PBGC1	44.66	35.35	3.91	0.13	0.01	0.02	0.67	0.13	0.02	0.01	<0.002	15.1	99.97	98.06
PBGA2	44.64	28.13	10.02	0.1	0.01	0.01	0.34	1.57	0.13	0.02	0.009	14.8	99.95	98.74
PBGB2	44.18	34.24	7.55	0.04	0.01	0.01	0.07	0.07	0.04	0.01	0.002	13.8	99.98	99.74
PBGB2	61.5	20.6	5.39	0.04	0.02	0.01	0.38	1.25	0.2	0.01	0.003	10.3	99.92	98.05
PBGC2	49.98	33.17	2.53	0.06	0.01	0.02	0.46	1.35	0.14	0.01	0.003	12	99.93	98.54
PGA1	60.62	21.05	6.46	0.06	0.01	0.02	0.14	1.2	0.08	0.02	0.012	10.2	99.95	99.20
PGB1	53.89	25.98	7.97	0.05	0.01	0.01	0.15	0.93	0.05	<0.01	0.018	10.8	99.96	99.35
PGC1	45.1	33.28	4.91	0.55	0.01	0.01	1.05	0.49	0.2	0.02	0.005	14.1	99.94	96.89
PGA2	43.7	26.78	12.15	0.19	0.04	0.01	0.29	1.26	0.11	0.03	0.017	15.3	99.95	98.75
PGB2	52.6	31.14	1.28	0.31	0.01	0.02	3.54	1	0.02	0.02	0.017	9.8	99.94	89.71
PGC2	51.43	29.32	4.61	0.06	0.01	0.06	1.02	1.47	0.05	0.02	0.003	11.8	99.98	96.42
MGA1	48.31	25.24	6.61	1.28	0.01	0.01	0.98	0.98	0.01	0.01	0.01	16.3	99.93	96.19
MGB1	52.88	20.45	6.52	2.21	0.3	0.25	1.35	0.72	0.01	0.02	0.003	15.1	99.92	91.50
MGC1	50.27	22.71	5.88	2.55	0.16	0.1	1.66	0.6	0.03	0.04	0.004	15.7	99.92	92.20
MGA2	48.55	24.77	7.79	1.82	0.09	0.05	1.8	0.88	0.02	0.04	0.005	14	99.93	92.74
MGB2	48.15	28.85	4.99	0.98	0.12	0.12	1.01	0.57	0.04	0.02	0.005	15	99.95	95.85
MGC2	51.35	24.46	5.23	2.73	0.02	0.08	3.12	0.44	0.03	0.03	0.004	12.2	99.92	88.37

Table 2: Concentration of major ions present in the water sample in the study areas. Units of E.C (µs/cm), TDS (mg/l) others (meq/l).

ELE	PH	E.C	T.D.S	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$HCO3^{-}$	Cl^{-}	$SO4^{2-}$	$NO3^{-}$
PBG1	5.7	489	367	1.14	0.73	0.71	1.41	0.57	1.92	1.08	0.35
PBG2	5.6	323	242	0.43	0.19	2.06	0.12	0.49	1.86	0.31	0.08
PBG3	6.3	366	275	0.75	0.38	2.12	0.10	0.75	1.51	0.48	0.40
PBG4	6.3	185	139	0.67	0.16	0.81	0.10	0.44	0.65	0.29	0.24
PBG5	6.7	222	167	1.10	0.27	0.55	0.17	0.79	0.80	0.52	0.09
PBG6	6.7	428	321	2.28	0.44	1.40	0.19	1.72	1.23	0.81	0.14
PBG7	5.1	224	168	0.30	0.22	1.01	0.25	0.25	0.92	0.39	0.52
PBG8	5.1	193	145	0.44	0.22	0.81	0.10	0.30	0.79	0.47	0.09
PG1	6.3	441	331	1.12	1.70	1.50	0.05	1.98	1.39	0.85	0.08
PG2	6.4	682	512	0.95	0.62	5.06	0.02	2.40	2.59	1.52	0.03
PG3	6.4	621	466	1.25	0.50	3.71	0.16	2.10	2.75	0.75	0.01
PG4	5.9	355	266	0.74	0.62	1.83	0.12	1.18	1.48	0.64	0.34
PG5	6.4	430	323	1.75	1.31	1.15	0.08	2.10	1.44	0.63	0.10
PG6	6.3	373	279	1.37	0.54	1.35	0.20	1.77	1.22	0.59	0.09
PG7	5.6	173	129	0.95	0.08	0.75	0.06	1.07	0.60	0.35	0.14
PG8	6.4	584	438	0.52	0.53	3.91	0.11	1.74	2.46	0.58	0.21
PG9	6.8	1133	850	3.11	1.47	5.47	0.24	3.31	5.27	1.29	0.09
PG10	6.5	734	551	1.71	0.87	3.51	0.38	2.10	2.79	1.17	0.10
PG11	7	306	229	0.82	0.61	0.94	0.25	0.93	0.74	0.50	0.43
PG12	6.8	430	323	1.42	0.68	1.98	0.08	1.72	1.62	0.75	0.05
MG1	6.7	407	305	1.76	0.92	1.18	0.15	1.50	1.23	0.73	0.47
MG2	6.9	168	126	0.41	0.35	0.73	0.02	0.43	0.73	0.34	0.11
MG3	7	230	173	0.77	0.77	0.54	0.04	0.61	0.79	0.60	0.08
MG4	7	408	306	1.66	1.11	1.30	0.14	1.75	1.19	0.75	0.25
MG5	6.8	592	444	3.05	1.21	2.15	0.05	2.75	1.76	1.01	0.52
MG6	6.8	591	443	2.16	0.73	1.35	0.41	1.77	1.54	0.80	0.50
MG7	7.2	348	261	1.37	0.45	1.25	0.25	1.44	1.00	0.63	0.36
MG8	7.3	273	205	1.04	0.61	1.07	0.04	0.84	0.51	0.67	0.72
MG9	7.3	700	525	2.14	1.79	3.47	0.10	3.33	2.10	1.15	0.30
MG10	7.3	482	362	1.61	1.35	1.92	0.05	1.95	1.58	0.96	0.34

Table 3: The Statistical Summary of Groundwater Controlled By Rock Type and Compared With W.H.O And E.U Drinking Water Standard

ELEMENTS	AVE OF MG Mg/L	AVE OF PG Mg/L	AVE OF PBG Mg/L	W.H.O 1993 Mg/L	E.U 1998 Mg/L
As	0.0006	0.0012	0.00082	0.01	0.01
Cd	0.0006	0.0001	0.00011	0.003	0.005
Cr	0.0022	0.0021	0.004	0.05	0.05
Cu	0.0027	0.005	1.0	2	2
Fe	0.36	0.48	0.6	0.3	0.2
Mn	0.054	0.10	0.16	0.5	0.05
Ca	19.35	27.6	32.4	75	NM
Mg	4.2	9.7	11.5	30	NM
Na	27.9	61.4	36.3	200	200
Ni	0.0009	0.0016	0.0014	0.02	0.02
Pb	0.003	0.0033	0.0042	0.01	0.01
Sb	0.001	0.001	0.001	0.01	0.01
Se	0.001	0.0008	0.001	0.01	0.01
Zn	0.015	0.02	0.023	3	NM
Al	0.25	0.4	0.50	0.2	0.2
Cl	55.65	89.6	36.8	250	250
Fl	0.79	0.82	0.82	1.5	1.5
NO_3	2.09	4.6	4.5	50	50
PO_4 SO_4	0.5 55	0.8 54.5	0.7 56	25 500	25 250

NM: Not Mentioned